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Papers on Hydraulic Engineering. By SAMUEL MCELROY, C. E.

(Continued from p. 223.)

No. 3.—PUMPING ENGINES.

FOR the supply of a pressing human necessity, for agricultural uses and other conveniences, from the various sources furnished by nature simply, or by nature and art, the mechanical skill of mankind has been called into use, in hydraulic machinery, simple or complex, from the days of the Genesis.

The various devices for raising water from running streams, ponds, lakes, wells, or cisterns, which have been in common use, transmitted from one generation to another, and placed on record by faithful observers, are studies of no ordinary interest and value. The single and double buckets worked by a simple cord or by a pulley, by band or by animals; the various forms of the wheel and axle, and windlass; the primitive well-swape, which, in the new world as in the old, yet lifts the "moss-covered bucket," dripping with benedictions to the way-worn and thirsty; the varieties of ancient noriæ; the chain pumps after their kind; the wooden and metallic hand pumps of numerous class:—these, with bellows pumps, persian-wheels, scoop-wheels, flash-wheels, rocking gutters, inclined screws, all the classes of centrifugal, rotary, and reciprocating pumps, *et id omne genus*, have well deserved

the elaborate attention paid them, by the scholars of past ages and by those of the present in the field of modern and antiquarian research.

While the romance of life has had adequate development beside the crystal wells and bubbling fountains, as the sacred writings and literary productions in our libraries abundantly show, the scientific literature of the present and past also shows, and especially in foreign tongues, with what care the difficult study of hydraulic engineering has been pursued, from distant ages. In the Italian, German, and French schools, the writings and records of such men as Vitruvius, Archimedes, Michellotti, Venturoli, Fischer, Eytelwein, Belidor, Dubuat, De Prony, D'Aubuisson, and their numerous contemporaries illustrate a profound appreciation of this most important department of research, which also pervades the more modern school of science.

So far, then, as certain fundamental laws and doctrines in hydrodynamics have been discovered and defined, as linked with the principles of natural science, the student of the present day may well feel as if much had been accomplished for him in this laborious field, and may take it for granted, amid all the pretentional flashes of new theories, that nature cannot but vindicate herself; and these clearly defined mechanical principles, which have come down to us with the sanction of authoritative age, like the doctrines of an exalted religious faith, may properly be valued and accepted as safe and infallible guides, which have borne the test of continuous trial.

Ignorance, however, and perverseness, have the same effect in mechanical matters as in religious, and each generation attempts within its limited period of action, in some directions, to controvert the accumulated testimony of all its predecessors, in those cases where it is wilful, or neglects this testimony in those cases where it is careless. Hence, the common exhibition of endless repetitions of fallible experiments, the constant re-invention of time-lost machines, the constant debates, pro and con, over long established principles, and the lamentable hindrances to systematic progress, because age is denied its prerogative of experience, and skepticism stumbles over the fallacy of personal re-invention and re-research.

Beside the effect of this absence of mechanical faith, the rapid progress in perfection of machinery, and the demand for increase in mechanical power, has had a strong tendency to throw into the shade the doctrines as well as the machines of past days; and while we must claim the universality and infallibility of principle, the correct application of principles to the new motors of the age may admit considerable discussion, and open the way to considerable misapprehension.

And it is in this particular that the engineering student finds himself at a loss, in the applications of hydraulic motors to the prominent uses and wants of the present day, as distinguished from the more simple machines we have briefly noticed. To investigate the several classes of pumping engines, with their numerous subdivisions, now in use, for mining and water works purposes, and to determine the most valuable, involves no little research.

While then it is plain that the records of the past are exceedingly

valuable on the score of doctrinal science, and by this we understand a science built upon correct experiment and observation in connexion with established general laws, it is much to be regretted that our records of actual results, as developments of doctrine, should be so meagre and imperfect. Too much of an engineer's life is spent in a round of experiments, probably made numberless times before, or being made by others, because no adequate records have been placed within his reach. The want of proper communications of this kind is severely felt, and a dignified profession falls short of the rank of a science, because it is oral and traditional, rather than liberal and established, from the neglect of its own members, who carry their acquirements into their individual graves, and are buried with a miserliness which robs the generation of their treasures. The growing disposition to more systematic publication is one of the good signs of the present day.

Another source of trouble arises from the fact, that too many of our book-makers, and particularly of the English school, are not engineers in practice, but mere collaborateurs, who get their information chiefly by asking questions—not being qualified to sift truth from error, who copy largely, and have no professional *esprit*. Of a large portion of the text books, treatises, and other works extant, how many authors are there entitled to rank as civil engineers. Like the institutions in fashionable vogue, which assume to graduate boys under age with a professional title, they are but blind leaders of the blind. But evils of this class and several others arise from the neglect of thorough-bred civil engineers to form themselves in an institution of mutual alliance, which we need not pause here to advocate.

The most casual glance at the state of pumping engine practice, at present, illustrates the general need of a more definite and systematic method. Engines of the most varied form and motion are not only to be found in different localities, but may sometimes be noticed in the same engine-house. In the city of Philadelphia, which has three distinct steam pumping supplies, three varieties of engines are at work in one house, two in another, and on the opposite side of the river are two more, different in class from either. In every direction, this class of construction seems to be treated as a matter of experiment, and the most extravagant outlays are sometimes made, with disastrous results; while the general standard of performance is unsatisfactory. It is plain that there is much need of a better order of things in this direction, and that the laws which govern pumping results with unalterable force, deserve a closer study and a more intelligent adoption; and it is equally plain that the present neglect of correct engineering oversight in construction is a fault to be remedied.

It is with the hope, therefore, that a reference to certain leading principles germain to this subject, which have been illustrated and confirmed by years of experimental observation, may be of service, that these papers are written.

General Analysis.—The question which interests us here is not confined to capacity for pumping, although capacity is important in its place. In those excursions about the country, which are frequently

seen, of commissioners who propose to decide questions of construction for themselves, while they frankly admit their ignorance of hydraulics, an engine at work is judged by its apparent power, its compactness of form, its paint and bright-work, and the energy of its advocates, and possibly its first cost. But the engineer understands, that while very rude and cheap engines may be forced up to a large delivery, or while engines may be tastefully decorated and finished, the true standard of judgment passes at once to those perfections in general design and separate detail, by which annual economy in service and durability may be best attained. It is a question of design, workmanship, and coal combustion, as well as of water delivery; a question of relative duty at the steam-piston, of losses by friction and otherwise, and of harmonious action with the column of water under motion.

These are not the standards by which pumping engines are often built; if they were, the curious multiplication of specimens around us would not exist. Other standards are admitted, and private interest, or political patronage, or culpable ignorance, or "much speaking," variously combined, influence boards of administration at the expense of their constituents. Instead of entrusting a matter of this kind to competent engineers, who will devise and adapt plans to the local requirements without sacrifice of principle, the pernicious practice is often adopted of advertising for plans, from which the board itself assumes the prerogative of judgment, however crude or contradictory the results. The adoption of an engine becomes a lobby matter; facts are falsified, reports and testimonies suppressed, and the result is necessarily injurious. It is mainly on this account that, however expensive our water works machinery and engine houses, and however well appointed, the standard of annual "duty" with us, falls far below that of the half-enclosed, massive, and rude engines of the coal mines across the ocean; not from want of outlay, or defective strength and finish, but from want of judgment in design and adaptation, and from neglect of the lessons of experience.

A pumping engine is to be considered in three divisions, which correspond with the usual division of its engine house into the pump room, the engine room, and the boiler room. In this problem of engine construction and performance before us, the pumps and main, the engine, and the boilers, although working in direct combination, are to an important extent independent in action, developing special principles under distinct operation, which affect the total result. And these principles cannot be neglected or perverted without injurious influence of one part on the other. These divisions may be noticed in this order:

PUMPS AND MAINS.

In water works and mining practice we find the class of suction and force lift pumps in general use, with various modifications of arrangement, as to pistons, buckets, plungers, valves, and other parts, as we also find various forms of mains in use.

There is a class of auxiliary steam pumps used for boiler feed, fire engines, building purposes, excavations under water, &c., where ease

of transportation, cheapness, compactness, and other special qualities influence their adoption, and where durability, appearance, and economy of use, are less important than in larger engines. These need not be more particularly enumerated, since they are controlled by the same principles which govern the others, and are valuable for their special departments only. And our reference, under the present division, to the larger pumps, after a notice of the rotary class, will be directed to the general features of valves, suction, force lift, and mains.

Rotary Pumps.—The successive improvements which may be traced through the class of water wheels as chief motors in transmitting power, in which the modern turbines are conspicuous, have also suggested a reverse action, by which the wheels and turbines are changed into pumps, of which many different patterns are now and have long been in use, operating as suction and force lift pumps.

The laws of maximum useful effect, which have been very fully and clearly demonstrated for water wheels, as types, apply to their reversed patterns, as to the form and arrangement of the blades, experiment having demonstrated a large increase of the discharge with a change from ordinary radial to properly curved arms, without increase of power. The following abstract of an experiment by Col. Morin, made at the Great London Exhibition, illustrates this point:—

Form.	Revolutions per minute.	Gals. raised per minute.	Height raised.	Useful Effect.
Curved Vanes (Appold's),	792	1164	18 ft. 8 in.	·649
" " "	788	1236	19 4	·680
Inclined " (45°),	694	560	18	·394
" " . .	690	736	18	·434
Radial, " . .	624	369	18	·232
" " . .	720	474	18	·243

With the best form of pump which can be devised, useful effect is controlled by velocity and lift, and the value of this motor is confined to low lifts under excessive speeds. Experiments made on Appold's centrifugal pump show a progressive per centage of work done, under a lift of 5·5 feet, with a 12-inch pump, of 21·2 per cent. for 375 revolutions, 59·1 for 400, 71·9 for 495, an increase to 607 revolutions giving 69·2 per cent. To raise water 67·66 feet, required a speed of 1322 revolutions; and within their special range of application, 70 per cent. useful effect is all that can be claimed for the best motors of this class.

The laws of form, however, have been much overlooked in those in ordinary use, radial blades being common in practice. For bailing large quantities of water from foundations in excavation, where the supply carries much sand and gravel, for wrecking pumps, and like uses, the facility with which dirt, gravel, grain, &c., are passed through these pumps is a strong point in their favor, while they have no claim to merit on the ground of economy in power.

About ten years ago, some of our scientific journals were agitated by a discussion of the merits of a new theory of centrifugal power, which proposed to regenerate the mechanical world, and overthrow the antiquated notion that a machine could not transmit more power than was imparted to it. It was claimed to be demonstrated at the end of much printing, and was admitted by some of our puzzled savans, that by certain mechanical adjustments an increase of velocity might generate a force of 173,824 foot-pounds from a power of 42,480, and twice the velocity would yield 695,296 foot-pounds for 84,960. But like all wonderful discoveries of the kind, which seem to lead a comet-ary life, it has vanished in silence from the horizon of mechanical science, to return no more, and to be numbered among the stame and cloud engines, caloric steamers, water gasometers, full steam cylinders, and other celebrities of the passing hour.

From the pertinacity with which some of our engine builders have urged the necessity of an equable motion in pumping, which we shall notice more particularly under another head, we have been somewhat surprised to see so much neglect shown to the rotary pump, which accomplishes their desideratum in the most perfect manner, and the fact of such neglect must be taken as a strong argument against the reliability and economy of this motor.

Pump Valves.—Among the more prominent kinds of foot and delivery valves used in pumping, are the "butterfly," "clack," and "double-beat" varieties. The first are made of leather or metal, generally the latter, opening with two wings, on either side of the bucket or plate to which they are attached. In heavy lifts, and in all cases where the water column is apt to be disturbed, they are objectionable from their manner of seating. In the Cornish mines, leather clacks, sometimes divided into separate openings, are considered in some respects preferable, on account of the effect of mineral water on cast iron valves, and a better cushion in seating; a valve of this kind in common use, is arranged so as to lift its hinges a short distance, giving a wider opening; but the double-beat valve has undoubtedly proved of great service in relieving the effects of concussion, and in reducing friction in mine work. This valve, which is so arranged with an upper and lower seat as to offer a minimum resistance to its lift, with a maximum outlet when unseated, is being generally adopted in water works engines, and fulfils its purpose admirably. The Brooklyn engine is working two of 54 inches opening, and two of 36 inches, under a lift equivalent to about 170 feet, and an enormous water delivery. The smaller valves play on the pump rods, and have wood seats, vulcanized rubber seats, first used, being found unreliable; the buckets are packed with lignum-vitæ, which has several advantages over leather or metallic rings.

A valve has been introduced in the engine of the Hull water works, England, which contains in 22 inches diameter, and in the form of a pyramid, 56 small circular cells, of about 2-inch opening, in each of which a gutta-percha ball is held, with a certain play. This arrangement aims at a free delivery, with light valves, which can be easily

replaced. Various forms of gratings have been adopted, with small india-rubber flaps, but in cases of heavy work they are not found durable.

For small pumps and moderate lifts, the use of "conical seat," "butterfly," "clack," or other light valves is admissible; but in heavy work it is important that the valves should give the largest possible channel of delivery, should open freely, should seat accurately, and be heavy enough to work down near the seat before the return stroke occurs. This feature of a pump deserves great care in arrangement, and exerts an important influence on the engine, and is more fully attained with the "double-beat" than any other valve. All valves should be protected from accident on account of interception by chips or other foreign substances, by carefully flooring the pump wells, and placing copper wire screens on the entrances, at such distance from the pumps as will obviate additional friction in supply. Flooring a well is also of service in preventing the effects of evaporation in the engine room on the bright-work. Those who are curious to see the operation of an umbrella over an engine, will find one in the engine house of the New York Navy Yard, the idea being original with one of the retired Commodores, and therefore not patentable.

Suction Lift.—It is customary to locate pumps rather with regard to convenience of position or of foundation, than any special attention to their action on the lower lift. It is considered a matter of little consequence what their relative level to the well may be, the preference being generally expressed for a short lift; but there are certain conditions of location, in all cases where location is not absolutely controlled, which seems to reverse the correctness of this general practice in illustrating an ancient and overlooked doctrine.

The Torricellian theory, which is an established doctrine of natural philosophy, has demonstrated that if a vacuum be found in a tube connected with a body of water, by virtue of atmospheric pressure, the water will rise to such height as corresponds with its specific gravity and a certain barometric state of the atmosphere, which height is limited, in certain latitudes, to 35·1 feet, and is usually assumed at 33·8 feet, or an equivalent pressure of 14·7 pounds per square inch.

It is evident that if the base of such a tube is closed by a cock, and the vacuum is made with an air pump, that the difference in atmospheric pressure in a height of 33·8 feet is so slight in practice, we may assert that it costs precisely the same mechanical work to produce this vacuum, either at the base, the middle, or the top of the tube. If the cock be opened, the tube is immediately filled, and the greatest load which can be shown in it by an indicator or vacuum gauge cannot exceed 14·7 pounds per square inch. It is certain that this load will be represented at the upper level of the water; if the atmospheric pressure on the water surface of the well is the same, plus only the difference due to 33·8 feet of its height of some forty miles, it is evident that the same gauge will show the same load at the base of the tube.

If, in consequence of rarefaction of the air contained in the water,

or imperfections of the air pump or tube, the vacuum is imperfect, the column of water will rise to a less height because the external pressure is in part balanced; but in this case, the gauge will indicate the difference in load whatever may be its position on the tube at the top, the middle, or the foot, and for the reason that the column of water is *in equilibrio* at each point of its elevation with the atmospheric column which sustains it. The equilibrium would be instantly changed if the lower valve of the tube were closed and the upper part opened to the atmosphere; in that case the atmospheric pressure would balance itself on the gauge, and at the middle or foot of the water column it would show a plus pressure, equivalent to the relative height of water above its piston; but so long as the tube is *in vacuo*, the minus pressure will be the same at any point of its height.

If we take the case of a piston moving in such a tube with an open top, packed air tight, and starting from the water surface, the water will follow it to a height of about 33·8 feet, and the load on the piston can in no case exceed 14·7 pounds per square inch, which will be its load at the maximum height. Now, if we reverse the analysis, we find that if by any influence of dynamic laws, such a piston in motion creates a perfect vacuum at any point below 33·8 feet, it is performing a certain amount of work in excess of the balance of the atmospheric column, and is wasting power in proportion to its travel under such vacuum.

All suction pistons work against an atmospheric load equivalent to the perfectness of their vacuum, and are supplied by a column of water lifted by an external, independent, counterbalancing force. If it should appear, then, that the vacuum to be produced by pumping action may be very seriously independent of the height of a pump, the question of location becomes important in the matter of economical work, and it is essential to make the universal, superincumbent, atmospheric load as useful as possible within its prescribed limits. The whole argument of the Torricellian theory is in favor of high lifts.

On the other hand, the theory of present practice asserts, that in all lift and force pumps, the piston bears a load equal to its area, and the weight of a column of water as high as the difference of level between the surface of the well and the point of delivery, without special regard to the relative height of the suction column.

We hold, then, that an important theoretical distinction is to be made between the upper and lower sides of any lift and force piston, in view of this law. The superincumbent load is represented by the pressure of the atmosphere, the friction of valves, piston, and water column, and the inertia of the latter, while the condition below the piston is represented by the perfection of the vacuum produced. The vena-contracta of the tube, valve friction, and inertia of the suction column, affect its relative height and velocity of influx, and are to be specially referred to the external atmospheric pressure which overcomes them in its effort to equilibriate the controlling vacuum. Strictly speaking, the mechanical work of such a piston is determined by

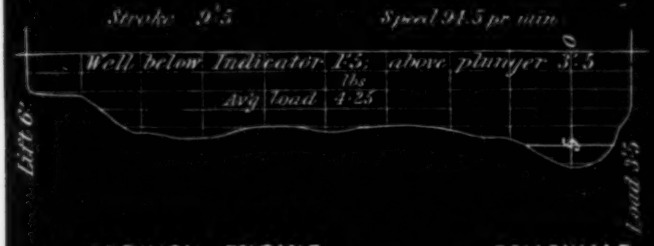
SUCTION PUMP CARDS.

Motion Right to left

CORNISH ENGINE. PHILADELPHIA.

June 19 1856.

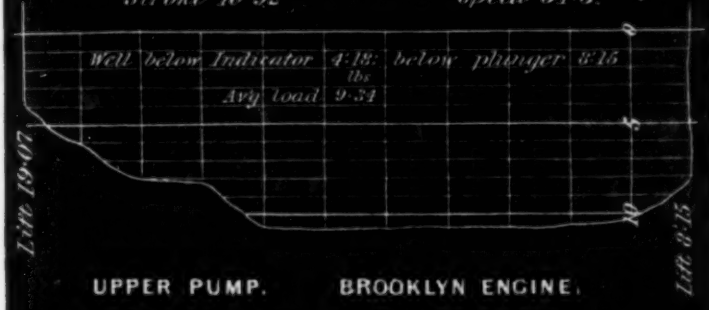
Stroke 9'5 *Speed 24.5 pr min.*



CORNISH ENGINE. BELLEVILLE.

J C W. Dec 20 1856.

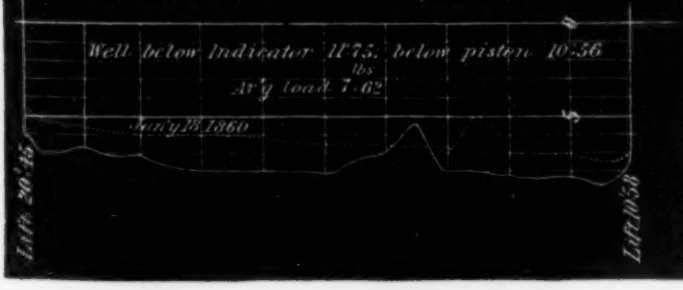
Stroke 10'92 *Speed 64'3.*



UPPER PUMP. BROOKLYN ENGINE.

Dec 23 1859.

Stroke 9'37 *Speed 105'6*



its upper load entirely, if we include in it that part of the atmospheric load, unbalanced by the imperfections of the vacuum beneath it.

The mechanical effort of the atmosphere brought into action by the pump, and measured by the pump vacuum, is exerted in overcoming the inertia of a body of water, at each stroke, equivalent to the piston area and travel, and the attendant frictions of supply. To the effects of such friction in loss of head, are to be added such losses or counterbalances as occur from leaking joints, rarefaction of air in the water column, barometric oscillations, and otherwise; we have also to make the stroke within the limit of height controlled by these losses, so that the maximum lift cannot in practice be carried up to the theoretical level; but the effects of this dynamic action, as we propose to show, not only contravene the received theory of action, but evidently justify a change of practice in certain cases.

All such pumps in established action work in more or less solid water, and should not of course be started at speed until properly charged above and below; precautions to this effect are always taken by careful engineers; and therefore, so far as water supply is concerned, with any full tube, and with a reasonable margin for the deductions of height we have noticed, there is no more danger of loss of charge at one lift than at another. This is not a serious contingency in any case of proper arrangement and workmanship.

To illustrate this question, reference is made to

Plate I. of Suction Pump Cards annexed, in which three pumping engines are represented, two of which are single-acting, and one-double acting, with different speeds and lifts.

The first card is taken from a plunger pump under a head of 3·5 feet, when the plunger commences its lift; but instead of showing an equivalent load, the indicator opens with a vacuum of over 3 pounds, which in the first foot travel increases to 6·25 pounds, the average load of the stroke being 4·25 pounds, equivalent to 9·77 feet, although the actual average lift is but 3 feet above the well. In this case the plunger diameter is 30 inches, the suction valves, double-beat, 43 and 39 inches diameter, and the actual speed 94·5 feet per minute.

The second card is also from a plunger pump which rests 8·15 feet above its well. Here the indicator opens with a load of 8 lbs., equivalent to 18·4 feet, which increases in the first foot to 10.5 lbs., and continues with an equivalent lift of 24·84 feet up to the seventh foot of the travel. The average lift is 21·48 feet, the actual average lift being 13·61. In this case the plunger is 34·75 inches diameter, with a double-beat valve in the same barrel, and a speed of 64·3 feet per minute.

In the third card, taken from a double-acting pump, the piston commences its lift with a load of 7·5 pounds, equivalent to 17·25 feet, the actual lift being 10·58. Before the first foot is traveled the load increases to 9 pounds, or 20·7 feet; the average load is 7·62 pounds or 17·52 feet, the actual average being 15·51 feet. In this case the diameter is 36 inches, fed by double-beat valves of 36 and 54 inches, the speed being 105·6 feet. The relative daily delivery of the engines of

the second and third cards, was 3,287,860 and 14,418,641 gallons, under total heights of 158·83 and 160 feet, through tubes of the same diameter.

In the first card the conditions of free delivery to the plunger barrel are exceedingly favorable, since there is a head of 3·5 feet, and there are very large suction valves, with a short passage from the forebay; yet, as we see, to start the column and maintain its flow, required an initial load of 14·37 feet in addition to that of the head, or about 16·37 feet at the first foot of travel. It was necessary, in other words, to create a vacuum to this extent, under the special conditions of work, and the inference is, that the entire extra lift thus exerted below the plunger, is lost in useful effect to the engine, which has to repeat it on the forcing stroke.

In the second card we see that to effect the stroke supply, required a maximum load of 24·84 feet, as distinct from the actual average lift of 13·61 feet. Here is then a second proof that the pump is badly located.

In the third card the maximum lift is 20·17 feet, the actual average being 15·51 feet; and the lesson taught in general is, the unquestionable advantage of a high suction lift, when we remember that the forcing lift is dependent on the relative level of the pump to the discharge.

This inference is correct on the basis that the indicator when attached to a tube *in vacuo*, represents correctly the atmospheric effort to meet the demand of the plunger or piston, whatever its relative position to such piston. It will be seen, however, by reference to published reports of pumping experiments, that the vacuum gauge is generally treated as if under the same conditions as a pressure gauge. At Philadelphia the card was modified by a deduction of 5 feet, equivalent to the water load and its level above the water, and at Belleville, the relative depth of the vacuum gauge below the force-main gauge, was credited to the pump. If the experts were correct, it is still evident that the nearer the suction piston can be carried to the level of maximum atmospheric balance, since the maximum load is fixed at about 33·8 feet, the better.

Another consideration flowing from a very plain law is important in suction tubes. It will be noticed in these cards, as in all other correct pump cards, in like principle, if not in the same degree, that the common theory of relative load is reversed, since the maximum is encountered at or near the commencement of the stroke, when the plunger is lowest, and the minimum at the point where the plunger is highest. In the first card the final load is 4 pounds, in the second card 3·8 pounds, and in the third card 3 pounds, less than the maximum initial load, instead of being regularly increased with increased lift. This is the effect of the *vis viva* of the suction column, which increases in power from the moment in which the initial atmospheric impetus overcomes its inertia; and the curves in the line traced by the indicator pencil, show the oscillations of this column, as affected by diffi-

culty or velocity of influx, and the promptness with which the initial effort is relieved.

This furnishes a second demonstration of the doctrine that the mechanical work of the piston is controlled chiefly by other conditions than that of relative level above the well, viz: by the freedom of influx to the pump chamber, and the dynamic movement of the column started by the pump.

It is plain, then, that the maximum useful effect of the suction side of the pump piston, is determined by the greatest elevation above the well consistent with the allowances due to barometric oscillations and imperfections of mechanism, and that the character and operation of delivery valves, form and length of supply tube, and speed of piston, are of great consequence to such effect. And it is also plain that the most judicious arrangement of appurtenances may be vitiated by an injudicious location of the pump.

In the single-acting engines noticed, as in all others of their special class, the steam-stroke of the engine makes the plunger lift, the return stroke being made under the pressure of a counterweight. Consequently the suction valve must be closed when the return stroke begins, and the *vis viva* of its column counteracted. Velocity cards, we have taken from the Philadelphia engine, show a relative speed of the ascent 18 per cent., hark 12 per cent., descent 70 per cent. of the entire double-stroke; at Belleville the descent was about half the speed of the ascent; but the speed is in neither case unfavorable to proper action; in the first card the influx evidently anticipates the action of the bucket. Here all the benefit of the *vis viva* of the column, at the instant when the valve closes on it, is not only lost, but it tends to increase the initial load on the return stroke by the force exerted to close it before the delivery valve opens to the main.

But in the case of the Brooklyn engine, which is double-acting, and in which the upper and lower pumps alternately relieve each other, this effect is not lost, since the line of motion is not counteracted, and the benefit is important as to the initial lift of the succeeding stroke and as to the loss of action of the pump. The relative variations in load are less than in the other cards, and were much improved in smoothness of action by subsequent improvements to the engine, which will be noticed under their proper head, and appear in the dotted line marked Jan. 13th, 1860, a fact which is remarkable, when the enormous difference in amount of water pumped in a given time is considered.

It may also be observed, that since the atmospheric effort to meet a vacuum produced by the abrupt motion of a piston, is retarded by all the causes which obstruct a flow of water in tubes, and a loss of mechanical effect occurs in this ratio, all contracted tubes, abrupt bends, imperfect valves, and the like, are to be avoided, with all counteractions in line of flow.

The general conclusion we present is this: that inasmuch as the vacuum produced in practice by pump motion is always in excess of the static load of an hydraulic column equivalent to its piston level,

and inasmuch as the limit to this vacuum is fixed, the greatest mechanical effect in suction will be realized by the highest upper centre of piston stroke, consistent with perfection of workmanship and arrangement, and that the conditions of action are different on different sides of any suction and force lift piston, and are independent of the relative height above the well to a greater extent than is commonly assumed.

Among other practical illustrations, which might be adduced on this point if space permitted, the relative locations of engine condensers, as to their supply wells, in stationary engines, and as irrelevant to the perfection of their vacuum, will be sufficiently familiar and suggestive.

(To be Continued.)

Strain on Arches and Suspension Chains.

From the London Artizan, August, 1862.

(Continued from page 243.)

In the foregoing sections of this treatise, we have given means of reducing the various strains to which structures are subject to direct strains, either in tension or compression.

In the present section we purpose investigating the resistance of materials to the various strains, and affording the co-efficients of stress, for the various descriptions of strain.

That strain which tends to shear or cut the materials transversely, has not yet been treated of, because of its extreme simplicity; thus it is evident, that the greatest shearing strain on a girder is that produced by the re-action of the supports, and the least shearing strain is at the point of the maximum horizontal strain, where it is nothing, and from which it increases to the maximum, in direct ratio to the distance from the point of greatest horizontal strain; let w represent the load per lineal foot on a girder, and let it be required to find the shearing strain at a point distant x feet from the point of greatest horizontal strain; then, if

$$\text{s} = \text{the shearing strain},$$

$$\text{s} = w\,x.$$

The resistance to torsion or twisting is called unit operation, in all kinds of shafts for driving machinery, in drills, boring bars, &c.

Friction adds something to the resistance of riveted plates; but as this kind of efficiency may vary very considerably according to circumstances, and is also liable to deterioration, we shall not lay down any rules for estimating it. The co-efficients of safety will supply information as regards the stress which may be safely applied in practice.

Resistance to Tearing.—If a cylindrical or prismatic bar, whose sectional area is a, is subject to a pull whose resultant acts along the axis of the bar, and whose amount is W, the intensity of the strain, or the strain per unit of section will be $= \frac{\text{W}}{a}$. The first effect of this

stress is to produce an extension of the bar, and if this extension does not exceed the limit of elasticity, the bar will recover its original form and size when the load W is removed; if the elongation proceeds beyond the limit of elasticity, a permanent set is produced and the strength of the material is deteriorated; and lastly, rupture of the bar is effected, the weight which produces it is termed the breaking weight, and is usually taken at per square inch of sectional area.

A sudden pull on a bar produces twice the strain that the same weight will effect when applied gradually, as the work performed by the constant force $\frac{W}{2}$ acting through a given space, is the same with the work performed through the same space by a force increasing at a uniform rate, from 0 to W.

Tensile resistance is also that which vessels subject to interior pressure oppose, such as water pipes, boilers, &c.; the formula previously given will apply to water pipes and other cylindrical vessels.

Let S = tensile strain per sectional square inch.
r = radius internal.
p = internal pressure per square inch.
t = thickness of the material in inches.

Then, $$S = \frac{p\,r}{t}.$$

For spherical vessels we have, if

W = total force.
A = sectional area.
$\pi = 3{\cdot}14159$, &c.

$$W = p\,\pi\,r^2, \quad A = 2\,\pi\,r\,t$$

$$S = \frac{W}{A} = \frac{p\,r}{2\,t},$$ hence spherical vessels are twice as strong as cylindrical ones.

The last equation will also give the longitudinal strain upon a cylindrical vessel; but as this is only half the circumferential strain, it is not taken into consideration in practice. It may be here observed that a sphere is the form best suited to resist internal pressure, as it has a maximum content, with a minimum surface, and if other forms are used it is found necessary to stay them internally with tie bars; cylindrical boilers only require the ends to be stayed, but square boilers require staying in all directions, and even then are not safe for very high pressures.

Resistance to Crushing.—We shall obtain the intensity of crushing stress by the same formula as is used for the tensile stress. The resistance to compression is exactly similar to that for tension, so long as the results of bending or buckling are not produced, and the formula for tensile strains will apply to compressive strains, in the absence of these results; thus the formulæ given may be applied to cast

iron columns, whose lengths are small compared with their diameters; also to cast iron pipes, condensers, air pumps, &c., subject to external pressure, but they do not hold good for less rigid materials, such as wrought iron.

The resistance to compression which is offered in bridge girders, &c., may be considered as unaffected by bending, &c., provided that they are well braced and of a rigid form.

We shall now proceed to consider the resistances opposed to compressive strains by long columns, and by their tubes.

Resistance of Pillars to Crushing.—Columns usually break, not by the direct crushing force, but by bending, which subjects them to strains similar to those produced by transverse stress, and generally rupture commences by fragments splitting off from the compressed side of the column.

Very short columns break by an oblique shearing action, or the sliding of one part over another, and occasionally two cones or wedges are formed which, being forced together, split and drive outwards the parts surrounding them.

We now proceed to the case where crushing takes place by bending.

Let W = the load acting on a long pillar or strut.
A = its sectional area.

Then one part of the intensity of the greatest stress is $p' = \frac{W}{A}$, where p' equals the stress per sectional unit.

Another part of the greatest stress is that which arises from lateral bending, and which will occur in that direction in which the pillar is most feasible, that is to say, in the direction of its last diameter, if the diameters are unequal.

Let d be that diameter, d_1 the diameter at right angles to it; let l be the length of the pillar, and v be the greatest deflection.

Then the moment of flexure $= W v$, the greatest stress produced by that moment is directly as the moment and inversely as the breadth and square of the thickness, if, $p'' = c \times \frac{W v}{d_1 d^2}$ where c is a constant to be determined by experiment.

But the greatest deflection consistent with safety, is directly as the square of the length, and inversely as the thickness, and $d_1 d^2$ is proportional to the sectional area s, and to the thickness d_1; consequently

$$p'' = c \times \frac{W}{S} \frac{l^2}{d^2} = c \times p' \times \frac{l^2}{d^2}$$

and the whole intensity of the greatest stress on the material being made equal to a co-efficient of strength f, is expressed by the equation—

$$f = p' + p'' = \frac{W}{S} \left(1 + c \times \frac{l^2}{d^2}\right)$$

and the strength of the pillar is expressed by

$$w = \frac{f s}{1 + c \times \frac{l^2}{d^2}}$$

A pillar rounded at both ends is of the same strength as a pillar of the same diameter, and twice the length; therefore, for this column, we have

$$w = \frac{f s}{1 + 4c \times \frac{l^2}{d^2}}$$

A pillar fixed at one end and rounded at the other, is a mean between the strengths of two similar pillars—one fixed at both ends and the other rounded at both ends. The following are the values of c and f, computed by Mr. Gordon, from Mr. Hodgkinson's experiments on pillars with flat capitals and bases. These values give the ultimate strength of the pillar.

	f lbs. per inch.	c
Wrought iron, . .	36,000	$\frac{1}{3000}$
Cast iron, ...	80,000	$\frac{1}{400}$

We will now consider Mr. Hodgkinson's formulæ, which being deduced from actual experiment, are, perhaps, the most valuable. The results of the experiments are:—

1. That in all long pillars of the same dimensions, the resistance to fracture by flexure is about three times greater when the ends of the pillar are flat than when they are round.

2. The strength of a pillar with one end round and one flat is an arithmetical mean, between the strengths of pillars with both ends flat, and rounded. Thus, of three cylindrical pillars, all of the same length and diameter; the first having flat ends, the second one end flat, and one round, and the third with both ends round, the strengths are nearly as 3, 2, and 1.

3. The strength of a pillar is increased about one-eighth by enlarging its diameter in the middle.

4. The index of the power of the diameter, to which the strength of long pillars of cast iron with rounded ends is proportional, is 3·76 and 3·55 in those with flat ends; or the strength of both may be taken as following the 3·6 power of the diameter.

5. The strength of cast iron pillars is inversely proportional to the 1·7 power of the length. Thus the strength of a solid pillar of that material varies as, $\frac{d^{3.6}}{l^{1.7}}$ where d represents the diameter, and l the length of the column. If d is in inches, and l in feet, for columns with flat ends.

$$\text{Strength in tons} = 44{\cdot}16 \times \frac{d^{3.6}}{l^{1.7}}$$

For columns with rounded ends,

$$\text{Strength in tons} = 14{\cdot}9 \times \frac{d^{3.6}}{l^{1.7}}$$

For hollow columns, of which

D = external, and d = internal diameter,

For those with flat ends,

$$\text{Strength in tons} = 44{\cdot}3 \times \frac{D^{3.6} - d^{3.6}}{l^{1.7}}$$

For those with round ends,

$$\text{Strength in tons} = 13 \times \frac{D^{3.6} - d^{3.6}}{l^{1.7}}$$

Strength of Short Flexible Pillars.—The above formulæ apply to all pillars whose length exceeds thirty times the diameter; for pillars shorter than this it will be necessary to modify the formula, since in these shorter pillars the breaking weight is a considerable proportion of that necessary to crush the pillar.

When the pressure necessary to break the pillar is very small, on account of the greatness of its length compared with its lateral dimensions, then the strength of the whole transverse section will be employed to resist flexure; when the breaking weight is half what is required to crush the material, one-half the strength may be considered as available for resistance to flexure; when the breaking weight is half what is required to crush the material, one-half the strength may be considered as available for resistance to flexure, the other half being employed to resist crushing; and, when, through shortness of the pillar, the breaking weight is very nearly equal to the crushing force, we may consider that no part of the strength is applied to resist flexure.

We may separate these effects by taking in imagination from the pillar by reducing its breadth as much as would support the pressure, and consider the remainder as resistance flexure to the degree indicated by the previous rules.

Let c be the force that would crush the pillar without pressure; d the pressure which would break it by flexure alone; b the breaking weight as calculated for long pillars; y the real breaking weight.

If we suppose a part of the pillar equal what would be crushed by the pressure d, taken away, we have $c - d$ = crushing weight of the remaining part, and $y - d$ the weight actually laid upon it, whence

$\frac{y-d}{c-d}$ = the part of this remaining portion which has to resist crushing, $\therefore 1 - \frac{y-d}{c-d} = \frac{c-y}{c-d}$ = the part to sustain flexure.

But the strength of the pillar, if rectangular, may be supposed to be reduced by reducing either the breadth of the computed strength,

to the degree indicated by the last fraction. In circular pillars this mode is not strictly applicable, but we obtain a near approximation to the breaking weight y, by reducing the calculated breaking weight c in that proportion.

Whence $b \times \frac{c-y}{c-d} = y$, the strength of a short flexible pillar b, being that of a long one, $\therefore b\,c - b\,y = c\,y - d\,y$,

and $$y = \frac{b\,c}{b + c - d}$$

In columns whose length is less than thirty times their diameter, with flat ends, there was noticed a falling off of strength due probably to incipient crushing, and the weight which produced this incipient crushing was about a quarter of the crushing weight. It is, therefore, assumed, that the greatest load to which a column may be subject, without injury by crushing, is a quarter the crushing weight, when the length of that column is about thirty times the diameter.

We shall have therefore $d = \frac{1}{4}$ in the preceding formula, whence in cast iron of the kind used in the experiments (Low Moor, No. 3),

$$y = \frac{b\,c}{b + \frac{3\,c}{4}}$$

The experiments on the absolute crushing strength of iron from which to determine the value of c, gave as the mean strength of one square inch section, 109,801 lbs. = 49·018 tons.

On some recently executed Deep Wells and Borings. By GEORGE R. BURNELL, C.E., F.G.S., F.S.A. Read before the Society of Arts.

From the Civ. Eng. and Arch. Jour., March, 1862.

(Continued from p. 229).

Some interesting artesian wells and borings have also been executed in various parts of England and of the continent, to a few of which I propose to return hereafter, but in the meantime I pass to the description of the great work lately completed at Passy, as being the one which has attracted the most universal attention. When the great works of the Bois de Boulogne were commenced, it was soon discovered that the pumps of Chaillot would not be able to furnish the quantity of water required for the lakes and waterfalls of the new park; and the municipal council of Paris, encouraged no doubt by the commercial results of the previous operation at Grenelle (which had eventually cost the sum of £14,000, and repaid its cost several times over), resolved to execute a second boring to the lower green sand, in order to secure an independent supply. It was originally proposed to execute this well of the same dimensions as that at Grenelle, that is to say, to finish with an eight inch bore; but before it was commenced, M. Kind, a German engineer (who had already carried out some very

important works upon a system, and by the aid of tools patented by himself) offered to contract for the new well, to finish with a bore of 2 feet in diameter, and to deliver the water at 92 feet above the level of the ground, at the rate of nearly 3,000,000 gallons per day. He undertook to complete the work for the sum of £14,000 within the space of two years. After some opposition, based principally on the doubts expressed by engineers who had been consulted on the subject, with respect to the increased delivery over that of the well of Grenelle, this offer of M. Kind's was accepted, and on the 23d December, 1854, the vote of the municipal council in favor of the contract with him was passed. The work was commenced shortly afterwards, and by the 31st of May, 1857, the boring had already reached the depth of 1732 feet from the surface, when suddenly the upper portion of the tube lining collapsed, at a distance of about 100 feet from the surface, and choked up the bore hole. This accident delayed the completion of the work for three years, and led to the rescinding of the contract with M. Kind; but the engineers of the city of Paris were so satisfied with his zeal and ability, that they entrusted to him the conduct of the remaining works. A new well was sunk to a depth of 175 feet 4 ins., and the boring was then cleaned out and resumed. Much trouble was encountered in traversing the strata below the distance of 1732 feet above quoted, and at length, at the distance of about 1894 feet from the surface, the first water-bearing stratum was met with, but the water, after several oscillations, did not rise to the level of the ground. The boring was continued below this level, until, on the 24th of September, 1861, at midday, at the depth of 1923 feet 8 inches, the true artesian spring was tapped. When this spring rose to the surface it discharged at the rate of 5,582,000 gallons per day. The yield has since then oscillated, but so long as the column had not been raised above the level of the ground, the total quantity does not seem to have fallen short of 4,465,600 gallons. The well of Grenelle (which by the way had been falling off in its yield for some time before the completion of the Passy boring, no doubt on account of some obstruction in its ascensional tube, but which for several days before the 24th Sept. discharged regularly 200,000 gallons per day,) fell in about 30 hours after the Passy spring had been tapped, to a yield of about 173,000 gallons, at which rate it remained stationary, until the tube of the Passy boring was raised so as to allow the water to stand at the same height in the two wells, when the original rate of delivery of the Grenelle well was resumed, but the rate of delivery of the Passy well fell to 2,000,000 gallons per day. It is intended eventually to cause the column of water of Passy to rise to a height of 1977 feet above the bottom of the boring, or about 54 feet above the surface of the ground. The horizontal distance of the Passy well from the one at Grenelle is about 3830 yards; and it will be observed that the water-bearing stratum is nearly 100 feet nearer the mean level of the sea at Grenelle than it is at Passy, whilst the surface of the ground is about 35 feet higher at the latter locality than it is at the former one.

Unquestionably the effect produced upon the respective sources of

supply, by the alteration in the heights of the columns of water, proves that the wells of Passy and of Grenelle are fed from the same stratum; and there can be no reason, therefore, to suppose that when the Passy spring shall have cleared its water passages there should be any difference in the qualities of the waters at the two places. M. Peligot has carefully analyzed the Grenelle waters, and he found that they contained 0·000142 of saline matters, composed principally of the carbonates of potash, lime, and magnesia, associated with a compound of sulphur and of soda of variable proportions and conditions, and with the carbonate of the protoxide of iron and silica. The salts of the sulphate of lime, or of the more permanently insoluble description, are absent, and it would appear that the gases diffused through the water are of considerable volume, the carbonic acid gas being one of the most so. There is a sensible evolution of sulphuretted hydrogen from both the wells of Passy and of Grenelle, and it is worthy of remark that the same gas is given off from the water in Mr. Gatehouse's well at Chichester, though in the latter instance the smell is sufficiently strong to render the water positively repulsive. At the present day the water at Passy is still foul, on account of the matters it brings up in suspension; but as in the case of the Grenelle well, this inconvenience will no doubt soon disappear. The temperature at which it reaches the surface is identical in the two wells, and is about 82° Fahrenheit.

It may be worth while to call attention to the mechanical means adopted by M. Kind in sinking a boring of the large diameter of 2 ft. 4 ins. to the enormous depth of nearly 2000 feet from the surface. The work was commenced by a shaft, as usually is the case, and after it had been sunk to a depth of about 50 feet the boring commenced, and was continued with as nearly as possible the same diameter to the bottom. M. Kind employed for this purpose what may be called rods with releasing joints, very closely resembling the joints introduced by Œuyenhausen, which allowed the cutting portion of the tool to be raised a certain height and then to be released automatically; this arrangement was adopted in order to avoid the lashing of the sides of the bore by the long rods, and to regulate the force of the blow. The cutting tool used by M. Kind also differed from the tools generally employed, for it consisted of a single or a double trepan, according to the nature of the ground, instead of the ordinary chisels and augers. A patent was taken out for these tools by M. Kind in 1854, the specification of which contains a series of engravings of the various modifications proposed for the various kinds of rock; in the *Annuare Scientifique* for 1861 illustrations will also be found of the ordinary trepans and of the slide joints. M. Kind is able, by these combinations, to strike as many as twenty blows in a minute with the greatest regularity at a depth of 2000 feet. The patent of 1854 specifies also certain methods of lining the sides of the borings; but it must be confessed that they do not seem to me to possess any great merit, and indeed M. Kind had more difficulties to encounter at Passy from the collapsing of his tubes than from any other cause. It is a common

error of well-borers to undervalue the effort exerted by clays swelling when charged with water; and the great delays encountered in sinking the Passy well were precisely caused by the false economy introduced in the execution of the tube linings. The time actually employed in sinking the Passy well was nearly the same as that employed at Grenelle; in the former instance it was 6 years and 275 days, in the latter it was 7 years and 90 days. The cost of the Grenelle well, as above stated, was £14,000; that of the well at Passy was £40,000; but it must be observed that the quantity of water, delivered at the same height in the two cases, is ten times greater at Passy than it is at Grenelle; the rates of delivery are, in fact, nearly in the direct ratio of the diameters.

I have not been able to learn whether the artesian wells of Elbœuf and of Rouen have been affected by the completion of the new well at Passy, and at present I am inclined to believe that they may escape this action, on account of their proximity to the entering ground of the lower green sands, on the western margin of the cretaceous basin. At Tours, however, so many wells have lately been sunk (in an early edition of M. Degoussé's excellent "Guide du Sondeur," that gentleman mentions that he himself had executed no less than 16 of them), that the subterranean supply is becoming exhausted, and, as in the case of the wells supplied by the basement beds of the London clay, the lower green sand wells are gradually losing their artesian character. In two wells also, at Evres and Ferrières, the subcretaceous formations yielded no water: and in the latter the bore was even carried to a depth of thirty feet in the great oolitic, or Jura limestone series, without obtaining a supply. I call especial attention to this fact, because it illustrates again the uncertainty at all times overshadowing the execution of the first deep wells in a particular district, and that the stratum which yields water in one locality is likely to be unable to do so in another. The enterprising gentlemen who are engaged at the Hastings well should bear this fact in mind; and though I believe that after they shall have traversed the lower members of the Wealden series, they are more than likely to find the upper or Portland oolite, which is of sufficient water-bearing power to insure them a good supply of water, they must also be prepared for disappointment. The Hastings well is already 553 feet deep, still in the Hastings beds, and as these have never yet been traversed, it is impossible to say whether they will be found to be seven or seventeen hundred feet thick. Most probably the former guess will be found to be the more correct, because the town of Hastings is situated at a low horizon in the series of Weald beds; but all operations of this description at Hastings must for the present be conducted in doubt as to the ultimate result, however strong may be the hopes of success. The character of the strata already traversed and of those likely to be met with at Hastings, leads me to believe that M. Kind's processes would be particularly applicable there, but the success of such an operation would still be a mere matter of speculation, such as ought to be left to private enterprise.

I dwell a little on this point, because the Board of Guardians of

Brighton are engaged upon a similar experiment, at a place called the Warren Farm, near that town. It is not my place to criticize the mode of execution adopted in carrying on this work, but I cannot refrain from saying that there are many things about it which seem to me to be in opposition to the opinions now entertained by scientific engineers; and I gravely suspect that, even if water from the subcretaceous formations should be obtained at this well, it cannot by any possible chance rise near the surface, which, at the Warren Farm, is not less than 410 feet above the mean tide level. It is inexplicable to me also, that this well should be continued by means of a shaft at the great depth already reached, instead of by means of boring; and I regret bitterly to see an experiment, which has been carried on hitherto with so much spirit, compromised by what I consider the mistaken course latterly adopted. At Brighton, nevertheless, the only chance of securing a supply in the parts of the chalk basin lying beyond the influence of the faults or "cross throws," which have, for instance, enabled the Water Works Company to obtain, as is said, one million gallons per day, is to penetrate the chalk to the lower green sand. Notwithstanding the cost of the previous experimental borings in the surrounding counties, I am convinced that the cheapest manner of effecting this object would have been to have bored, rather than to have sunk a shaft, and even now the Guardians would do wisely to adopt this course, especially as theirs is really the first experimental shaft or boring on the east bank of the Arun. It is, however, a sad peculiarity of the municipal bodies of England, that they are always disposed to listen to those whom it is the fashion to call "practical," in contradistinction to "scientific" men, as though the mere fact of working "by rule of thumb" gave men truer insights into the laws of nature than long study and careful observation. At Brighton this seems emphatically to have been the case, and in a report addressed to, and received by, the Board of Guardians, the opinions of three practical well-borers are quoted as to the probable cost of continuing the well at Warren Farm, but no opinion seems to have been asked from such men as Mr. Hawksley, Mr. Mylne, or Mr. Homersham, who have brought great experience and deep study to bear on the hydrographical conditions of this district on other occasions. It is one of the fashionable theories of the day that a scientific education incapacitates a man for the exercise of a profession, and that the most able men in any branch of art or science are those who have not been brought up to pursue it. Under these circumstances it may not be surprising, however unfortunate it may be, to find empiricism preferred to science, or that the Brighton Guardians should avoid taking the opinions of really eminent engineers.

In stating, in the previous part of this paper, that I should return to the question of the abnormal beds met with at Highgate, I had especially before my mind's eye the case of the well sunk under my own orders at Warnham Court, near Horsham; and at Red Hill, by my friend Mr. Docwra. In the former case, the boring, after it had been carried through the sandstones, clays, and shales of the upper

Wealden deposits, passed at a depth of 142 feet from the surface into a bed of red clay and sandstone intermixed. At first, I believed, from the external characters of the materials, that they were of the same nature as the beds found at the bottom of the Kentish Town well, and I was supported in this opinion by several distinguished geologists to whom I showed the samples. As the Kentish Town beds were, at the time I refer to (about five years since), universally considered to be members of the new red sandstone series, of course I regarded the Warnham bed as one of the same range. But Mr. Docwra, at Red Hill, after he had traversed the sands and loams of the subcretaceous series to a depth of 438 feet, passed into a bed composed of red clays and particles of red sandstone, which were identical with the Warnham beds, and with some members of the Wealden series. It seems, therefore, to me to be very probable that the Kentish Town beds may be members of the Wealden series, but the solution of this question has simply a geological interest, for alike, the Weald clays and the new red sandstone clays, are without water; and, under these circumstances, the wisest course to be adopted was to stop the further progress of the works in all such cases as Warnham and Red Hill, unless they were carried on distinctly as philosophical experiments.

The well at Rugby, though it has proved to be, no doubt, a source of annoyance and disappointment, may eventually turn out to be of importance to the commercial interests of the locality. It was commenced with the hope of finding in the new red sandstone series under the lias, some water-bearing strata which might be able to furnish a supply to compensate for the deficiency under which the town of Rugby was suffering, after it had been put to the expense of carrying out the absurd crotchet of the so-called "gathering grounds" system. A boring has here been carried down to a great depth in the new red sandstones of the triassic group, which, at Liverpool and Birkenhead for instance, frequently supply large quantities of water. At Rugby, however, the boring at present has only yielded a brackish water, and I suspect that now all hopes of securing the result desired by the Local Board of Health by this well must be abandoned, unless the Board determine upon tubing the bore-hole throughout its length, and upon continuing to sink to a much greater depth. It is possible that, within a moderate distance from the bottom of the present well, stronger brine springs than those now brought to the surface may be found, which it would be possible to evaporate economically for the purpose of salt making; but a very careful comparison between the strata of this locality, and of those near Derby or Droitwich, would be required before any decided opinions could be formed as to the probability of finding soft water within a reasonable distance from the surface at Rugby.

The well at Great Yarmouth, executed by Sir E. Lacon & Co., is of interest, on account of its showing the great depth attained by the tertiary strata on the east of England; but, unfortunately for the spirited proprietors, the results, so far as water supply is concerned, have been "negative." The depth of the tertiaries here was found to be

527 feet, and the first 170 feet of this thickness were composed of recent estuarine and blown sand, deposits of very recent formation. At Norwich, the Messrs. Colman are steadily pursuing an experimental boring, which has already passed through the chalk to a depth of 1158 feet, the upper green sand to a depth of 8 feet, and the gault to a depth of 30 feet; the works have been suspended in this formation on account of some accident to the machinery, but when this shall have been repaired they will, no doubt, be resumed. It may be necessary to descend 150 feet lower before reaching the water-bearing stratum, but the comparative success of Mr. Lankester Webb's well, at Stowmarket, affords good reason to hope that Messrs. Colman's perseverance will ultimately be rewarded. I do not anticipate, however, that the water will overflow the surface, because the lower green sand is traversed by one of the affluents of the Ouse, near Downham Market, at a comparatively low level.

In a paper which I had the honor of reading in this room last year, I alluded to the very successful borings made by the Kent Water Works Company, in the Ravensbourne Valley, and this evening I am enabled to lay before you a section showing the strata they traversed. One reason for my doing so is, because I have heard that some parties propose, as I said in the opening paragraph of this paper, to sink artesian wells near London for the supply of the metropolis; and I think it desirable to state for their guidance, that unless they meet with the peculiar conditions of the faults of the Ravensbourne Valley, they are not likely to obtain a large supply of water from the chalk on the north side of the Thames, whilst there is no chance whatever of their finding water below the chalk. There are, no doubt, copious and beautiful springs given off from the head valley of the Lea and the Coln, both of which rise in, and are fed by, the chalk; but those springs may, in almost all cases, be shown to be connected with some geological disturbance of the strata: and the only locality near London where there seems to me to be any chance of obtaining a large quantity of water from the chalk, would be on the left bank (or the west) of the river Lea, somewhat to the north-east of Stratford, because there is about that district a line of disturbance in the chalk parallel to the great fault which brings to the surface the springs lately tapped near New Cross, and those of Grays in Essex.

Finally it must be evident to any one who reads attentively the records of the success and of the failure of the attempts above mentioned, that the execution of artesian wells is an operation which should only be entrusted to skilful and well-tried men, acquainted with the theory and practice of this art. No such work should be commenced without a careful preliminary survey of the geological and hydrographical conditions of the country extending over a very wide range. This is seldom done, because public bodies, in England at least, do not seem to object to pay for engineers' blunders and miscalculations, but they do object to pay for their study; and it is at once assumed that because artesian wells have succeeded in one case they must succeed in all. But even when the greatest amount of skill and sci-

ence have been brought to bear on the preliminary investigations for the establishment of an artesian well, it is impossible to predict with any certainty what the result of sinking a shaft or a boring may be in a stratum hitherto untried. Moreover, every artesian source of supply is limited in amount, and even in the case of the Paris basin, it would be desirable to watch the effects of the increased draft upon the lower green sand during a dry summer, especially before commencing, as has been proposed, the execution of a large number of wells like those of Passy and of Grenelle.

The student who may desire to obtain a complete view of the subject thus briefly referred to, would do well to consult the works of Messrs. Prestwich, Mylne, Clutterbuck, Homersham, Degoussée, Burat, Hericart de Thury, Garnier, &c., the Transactions of the Institution of Civil Engineers, the Comptes Rendus of the Académie des Sciences, and of Les Ingénieurs Civils of France. I am myself under great obligations to Messrs. Hawksley, Lockwood, Wells, Chamberlain, Docwra, Prestwich, Morris, Snyder, and others, for the sections and information so liberally supplied to me.

I may here add, that in the number of *La Presse Scientifique*, for Jan. 16 of this year, I find a notice of a well lately sunk at Columbus, Ohio, U. S., which is not less than 2575 feet deep. The thermometer (on the system invented by Mr. Walferdin) registered a temperature of 88°; this would seem to show that the law of the increase of temperature is rather slower in Ohio than it is near Paris. No particulars are, however, given of this important boring.

The Economic Construction of Girders.

From the Lond. Civ. Eng. and Arch. Journal, July, 1862.

(Continued from page 239.)

Girders of great Spans.—It was our intention to have given in the present paper some general account of the principles to be employed in investigating the economic merits of girders of spans so great that most of their strength is absorbed in supporting their own weights; and we naturally chose the Conway Tubular Girder Bridge as an existing example with which to compare the results for other methods of construction; for as that bridge has only one large span, the calculations were free from the complications which continuity over the piers would introduce, and Mr. Edwin Clark's descriptive work afforded us that complete insight into its construction so necessary for our purpose.

But a careful examination of the stresses acting on the material of the Conway tubes has led us to the conclusion, that these stresses are far in excess of what has on every hand been considered judicious. In no case has it ever been thought prudent to place the material of a bridge under a greater stress than one-third of that which would break it; but the result we have arrived at in the case of the Conway tube is, that were it loaded at the rate of one ton per foot run, in ad-

dition to the bare weight of the tube itself, and at the same time subjected to the effects of a wind-storm equivalent to a force of 30 pounds on the superficial foot; then, taking the most favorable view of the action of the parts, the stress per inch would be fully one-half of that which would cause rupture.

Impressed with the importance of the subject, and, with a view also to urging the adoption of a means of partially remedying this unsatisfactory proportion of the stresses, we make the strength of the Conway tubes the subject of our present paper; postponing to our next the more general treatment of the subject of girders of great spans.

—

THE STRESSES ON THE CONWAY BRIDGE TUBES.

We take the standard work of Mr. Edwin Clark as our text-book in treating on this subject; and although the results of our own calculations differ widely from his, and we are constrained to point out some errors into which he has unaccountably fallen—unless it be from the difficulties in the way of revision of such investigations and hurry for the press—we beg to record our high appreciation of his work generally, and our admiration for the spirit in which it for the most part is written, and for the great amount of valuable practical information, and the important original views and investigations which it contains.

We shall, in the first place, point out what we consider the sources of error in Mr. Clark's two principal calculations of the strength of the Conway tubes. Next, we will give our own investigations of the stresses thereon, exclusive of the effects of wind-pressure. Third, we shall point out what amount of light the large experimental girder is capable of throwing upon the subject. Fourth, we shall treat of the additional stresses resulting from the lateral action of the wind—omitted in all the previous calculations; and, fifth, conclude with suggestions for strengthening the tubes.

1. *Mr. Clark's Calculations of the Strength of the Conway Tubes.*—As both the calculations which Mr. Clark gives (see pages 748 and 754 of his work) employ a constant derived from the experiments made upon the large model girder of 75 feet span, it will be best in the first place to inquire into the nature of this constant. The description of the experiments is given at pages 158–189, and the constant, which we represent by the letter Q, is thus derived—

$$Q = \frac{W S}{8 D A} \quad . \quad . \quad . \quad . \quad (1)$$

where W is the total distributed, or twice the central breaking weight in tons, S = the span, D = the depth for calculation, and A = the sectional area of the bottom in inches; and by this formula in another dress, Mr. Clark (187) obtains the values for Q in the following table, from the experiments numbered I, III, and IV, or those in which the failure took place by the rending of the bottom:—

TABLE I.—*Experimental Girder, 75 feet span.*

	Sec. of Top.	Sec. of Sides.	Sec. of Bottom, or A.	Value of q.
Experiment I,	23·4	9 or 9·6	8·8	19·0
" III,	23·4	9 or 9·6	12·8	20·3
" IV,	23·4	9 or 9·6	18·31	16·6
Average,				18·6

This average value, 18·6 tons, of the constant Q is at page 748 denominated the "ultimate tensile strain of riveted plates;" and from having been looked upon in this light it has vitiated both calculations; it is, in fact, an expression for the whole tensive action of the section referred to the same leverage with which the bottom acts, compared with the sectional area A of the bottom; and by heaping on material to the sides and top, without altering A, any value may be obtained for Q; in fact, this is virtually done in the experiments I and III, in which the sides and top are in excess compared with the bottom. The 4th experiment, for which Q = 16·6, is the only one with an approach to the proportions of the Conway tube. But when the sides are made unduly thick, as in I and III, the proportionate aid derived from their resistance to rupture is increased; and when the top is made unduly heavy, as in the same experiments, the position of the neutral axis is raised higher, so as to afford a longer leverage to the tensive stresses in the sides and bottom: in fact, as we shall have occasion to show, the actual stress on the material of the bottom in experiment No. I was, when it gave way, *less* per inch than in experiment No. IV.

There could be no strong objection to employing a constant of the nature of Q in the comparison of structures of different dimensions, if their cross sections were exactly similar; but even here the last experiment fails to be altogether applicable to the case of the Conway bridge, since the constructions of the bottom differ considerably.

Mr. Clark's first calculation of the Conway is analogous to that employed in deriving the values of Q in the table; there is therefore no material objection, except that just referred to, to be taken to it so far as it goes, if the value of Q as derived from experiment No. IV be employed—that is, 16·6 instead of 18·6 tons. It is to be regretted, however, when a near approach to the best proportion of section was attained in the large girder, that then more experiments were not made upon it.

Mr. Clark's second investigation is of a more elaborate character, taking into account the influence of the sides, and made with a view to calculating the actual stresses per sectional inch brought upon the extreme top and bottom plates by given loadings. Passing over minor objections, we are at once arrested by the manner in which the first results arrived at are applied—not with a reference to the actual strengths of plates as given by the direct experiments recorded at p. 376, after a proper deduction being made from these for rivet holes—but by employing the unfortunate *constant* Q, derived in such an ob-

jectionable manner from the girder experiments, and by a mode of treatment that ignores the sides. Had a constant been deduced from these experiments by a treatment in accordance with the principles of the second investigation, and that constant been employed instead of Q, little would have remained to object to, except that the difference in the constructions of the bottoms would—as we shall afterwards explain—have told unfavorably upon the constant so obtained. If, on the other hand, we take the average result given for absolute strength at page 376, viz: 19·6 tons on the solid inch, and estimate the metal lost by rivet holes at only 15 per cent. of the total section, this leaves ·85 of solid plate out of every inch of section, and (supposing the plates to receive no injury except in the rivet holes, and to act all harmoniously together) the absolute strength estimated over the whole plate will be $= 0{\cdot}85 \times 19{\cdot}6 = 16{\cdot}66$ tons; the correct constant, according to these views, to be used with the primary results of Mr. Clark's second and more complete investigation, instead of the incompatible so-called *constant* 18·6.

2. *Our Calculation of the Stresses on the Conway Tubes.*—The sectional areas at the midspan of the tube as given by Mr. Clark at p. 589 are, for the top = 645·30, for the sides = 257, for the bottom = 535·65; total = 1437·95.

No details of the calculations of these areas are given, but the plans and descriptions afford sufficient information for making an independent estimate, and since the sectional areas we so arrive at differ somewhat from those given by Mr. Clark, we add the particulars:

Estimate of the sectional area of the top of the Conway, including all the attached angle irons.

	Sq. inches.
A and B plates = 14′ 9″ × 1½″ . . . =	265·5
X plates = No. 9 × 21″ × ¾″ . . . =	141·75
Strips = No. 16 × 9″ × ½″ . . . =	72·0
Angle irons, No. 40, 4½ in. sec. . . =	180·0
Total, . . . =	659·25

Estimate of the sectional area of the sides.

Two sides, each 21′ 7″ × ½″ . . . =	259·5

Estimate of the sectional area of the bottom, including all the attached angle irons.

	Sq. inches
D and E plates = 14′ 8″ × 2″ . . . =	352·0
V plates = No. 7 × 21 × ½″ . . . =	73·5
Angle irons, No. 28, 2·7 in. sec., . . =	75·6
" No. 4, 4·5 " . . . =	18·0
Two packings P, not continuous, . . =	0·0
	519·1

Let us suppose the horizontal plates A, B, D, and E, together with their attached angle irons, to become concentrated into the lines passing through the centres of their thicknesses, as in diagram 2; let also all the X and V. plates be brought together, as also the side plates, as in the diagram. Further, let the sides be completed by material taken from the angle irons that connect them with the B and D plates, so as to make up the length to B D without affecting their combined

thickness, which is equal to one inch. Let *c* be the centre of the depth X V between the centres of the cells, and let *n* be the position of the neutral axis.

The measurements carefully obtained from the plates are:—

A E = 25·343 feet, B D = 21·698, A B = 1·813, D E = 1·833, C V or C X = 11·760. The sectional areas, after making the adjustments, indicated above, are—A plates, &c., = 254·25; B plates = 267,375; X plates = 141·750; whole of top = 663·375; D plates = 230·80; E plates = 213·80; V plates = 73·50; whole of bottom = 518·10; whole of sides = 260·38. Then by a sufficiently accurate calculation we find the centre of gravity *n* of the section* to be 1·185 feet above the centre *c*; hence we have $h_1 = 13{\cdot}862$, $h_{11} = 11{\cdot}482$; $i_1 = 12{\cdot}029$, $i_{11} = 9{\cdot}669$;

$$\frac{i_1^2}{h_1} = 10{\cdot}4384, \text{ and } \frac{i_{11}^2}{h_{11}} = 8{\cdot}1423.$$

DIAGRAM 1, showing the plates, &c., in half of the mid-span section of the Conway Tube.

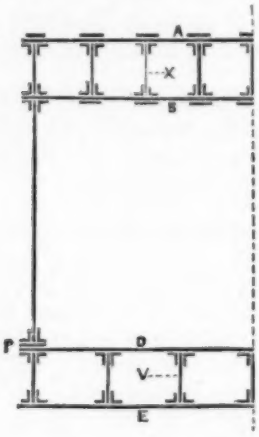
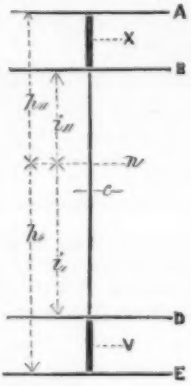


DIAGRAM 2.



We may now deduce a general formula for the moments of the various stresses on the parts measured round the neutral axis *n*. Let us deal, in the first instance, with the moments of the parts in a state of tension, that is, those below the neutral axis. Let T be used to represent the greatest tension per sectional inch on the solid metal of the weakest section; or, in other words, on the sections of the extreme plates E as above given, but having a deduction made from that section on account of the loss by rivet holes. Let the proportion of solid metal to the total area at the weakest section be as *e* 1, so that *e* T will express the tension per square inch as measured over the total section without deduction of rivet holes; *e* T is the tension we have to do with in relation to the position of the neutral axis, when the slight influence

*An interesting question here presents itself as to the effect the rivet holes in the bottom and sides will have upon the height of the neutral axis. In the text, we follow with regard to the position of the neutral surface, the ordinary rule of taking it at the height of the centre of gravity of the section; and though we believe this is by the above cause rendered not quite exact, it must be sufficiently so for this and ordinary calculations.

of the rivet holes thereon is neglected. The corresponding compressions per sectional inch at the extreme layers of the material on the other side of the axis will be expressed by the letter C, and this will be equal to $\frac{h_{11}}{h_1} e\,\mathrm{T}$.

For the moments of the parts in tension we have then the following formulæ :—

For plates E, area = E, degree of tension = e T, leverage = h_1;
$\therefore$ moment = $e\,\mathrm{T} \cdot \mathrm{E}\,h_1$.

For plates D, area = D, degree of tension = $e\,\mathrm{T}\,\frac{i}{h}$, leverage = i_1;

$$\therefore \text{moment} = e\,\mathrm{T} \cdot \mathrm{D}\,\frac{i^2}{h}.$$

For Side Plates.—For any horizontal layer of these distant x from the neutral axis, and dx thick, the breadth being 1 inch, the area $= dx\,b$, degree of tension $= e\,\mathrm{T}\,\frac{x}{h}$, leverage $= x$; therefore the moment $= e\,\mathrm{T}\,b\,\frac{x^2}{h}\,dx$. Integrating this between the limits $x = o$ and $x = i$, we have (noting that the i which arises from the summation of the thicknesses of the layers must be taken in inches) moment $= e\,\mathrm{T}\,b\,\frac{i^2}{3\,h}\,12\,i = 4\,e\,\mathrm{T}\,b\,i\,\frac{i^2}{h}$.

For Plates V.—Without altering the sectional area of these plates, we will suppose them to become stretched out to the full extent of D E, the united thicknesses becoming $= t$. The moment of any layer dx thick, and distant x from the neutral axis, is $= e\,\mathrm{T}\,t\,\frac{x^2}{h}\,dx$; integrating this between the limits $x = i$, and $x = h_1$, we have moment

$$= e\,\mathrm{T}\,t\,\frac{12}{3h}\,(h^3 - i^3) = e\,\mathrm{T}\,12\,t\,(h - i)\,\frac{1}{3h}\,(h^2 + h\,i + i^2)$$

and putting V = the sectional area, moment $= e\,\mathrm{T}\,\mathrm{V}\,\frac{1}{3}\left(h + i + \frac{i^2}{h}\right)$

So that the sum of the moments of the plates, &c., below the neutral axis is

$$= e\,\mathrm{T}\left\{\mathrm{E}\,h_1 + \mathrm{D}\,\frac{i^2}{h_1} + 4\,b\,i_1\,\frac{i^2}{h} + \tfrac{1}{3}\,\mathrm{V}\left(h_1 + i_1 + \frac{i^2}{h_1}\right)\right\} \quad . \quad . \quad (2)$$

And similarly, the moments of the parts above the neutral axis are

$$= \mathrm{C}\left\{\mathrm{A}\,h_{11} + \mathrm{B}\,\frac{i^2}{h_{11}} + 4\,b\,i_{11}\,\frac{i^2}{h} + \tfrac{1}{3}\,\mathrm{X}\left(h_{11} + i_{11} + \frac{i^2}{h_{11}}\right)\right\} \quad . \quad (3)$$

Applying these formulæ to the Conway bridge, with the values given above for the various factors, and noting that $b = i^{11}$, we have

$$\left.\begin{array}{l}\text{Moments of parts}\\ \text{under tension}\end{array}\right\} = e_T\,(213{\cdot}8 \times 13{\cdot}862 + 230{\cdot}8 \times 10{\cdot}4384 + 4 \times 12{\cdot}029 \times 10{\cdot}4384 + 73{\cdot}5 \times 12{\cdot}11) = e_T\,6765{\cdot}3.$$

$$\left.\begin{array}{l}\text{Moments of parts}\\ \text{under compression}\end{array}\right\} = c\,(254{\cdot}25 \times 11{\cdot}482 + 267{\cdot}375 \times 8{\cdot}1423 + 4 \times 9{\cdot}669 \times 8{\cdot}1423 + 141{\cdot}75 \times 9{\cdot}764) = c\,6790{\cdot}3.$$

$$\text{But } c = \frac{h_{11}}{h_1}\,e_T = 0{\cdot}8283\,e_T \quad \therefore$$

$$\text{Total moment of section} = e_T\,(6765{\cdot}3 + 0{\cdot}8283 \times 6790{\cdot}3) = 12390\,e_T.$$

Now the resulting moments of the loading on half of the span and the re-action of the pier must be made equal to this; this moment is equal to $\frac{1}{8}\,w\,s$, w being the total distributed weight over the span s, and if we take $s = 400$ feet, this becomes $= 50\,w$;

$$\left.\begin{array}{c}\therefore\ w = 247{\cdot}8\,e_T,\ 50\,w = 12390\,e_T,\ e_T = \dfrac{w}{247{\cdot}8}\\ \text{and } c = 0{\cdot}8283\,e_T\end{array}\right\} \quad . \quad . \quad (4)^*$$

We may remark upon the above calculation, that it is made favorable to the strength of the bridge; 1st, on account of the full sectional area of the angle irons being taken instead of that of their covers, which would be the more correct course; 2d, the span s as above is the *clear* span, but the span for calculating the moment of the re-action of the pier, &c., should be the distance from the centre of pressure on one pier or abutment to the centre of pressure on the other, or probably here about 405 feet; 3d, the weight of structure and loading is, of course, equally underrated with s; and 4th, the material composing the sides has been estimated at the same standard as the bottom, to withstand tension; the sides should however be considered inferior, both on account of being single riveted, and from the plates composing them being placed with the fibre vertically, or at right angles to the tensive longitudinal stress. The experiments given at page 377 of Mr. Clark's work show the absolute strength, when the stress is parallel to the fibre of the plate, to be about three tons greater than when at right angles thereto; but when the sides proper do not descend to the lowest part of the girder, their absolute strength is not called forth, and it may be that they therefore contribute as much to the support of the structure as though of better material and workmanship.† When, however, as in the large experimental girder of 75 feet clear span, the

* We do not put much stress upon the difference in the values we have employed for the sectional areas of the parts from those given by Mr. Clark, for the results when his values are used are almost the same. Thus, taking the sections in the table at page 589, we find $h_1 = 13{\cdot}577$, $h_{11} = 11{\cdot}777$, $i_1 = 11{\cdot}744$, and $i_{11} = 9{\cdot}944$; and proceeding with the calculation as in the text, with the following values of the parts A = 250, B = 254, X = 140, Sides = 260 or 1 inch thick, D = 237, V = 75, and E = 222, we get these results:—

$$w = 248{\cdot}42\,e_T,\ e_T = \frac{w}{248{\cdot}42},\ \text{and } c = 0{\cdot}82653\,e_T,$$

only differing from the results in the text by about one-quarter per cent.

† This supposes the elasticity to be the same as for the bottom plates. If we once open up the question of using iron of different elasticities, numerous interesting, but complicated, problems present themselves. Good results would, for instance, be obtained by choosing and placing the plates so that those with the greatest powers of ultimate extension would be situated further from the neutral axis, and those with least elasticity nearest to it.

sides descend to the bottom, and have therefore their lowest layers subjected to the same extremes of tension with the bottom plates, their absolute strength and ultimate extensibility become important points. If, with the same ultimate extensibilities, the net strength of the side plates is inferior to that of the bottom, a deduction should be made from the moment expressing their efficiency; and if the ultimate extensibility of the side plates be inferior to that of the bottom, rupture will begin in the sides before the bottom plates give out their full strength. In accordance with these views, we do not think it necessary to make any deduction from the moments of the Conway section; but when we come to treat of the experimental tube, it will appear that some such deduction is required in its case, the effect of which will be to slightly augment the ultimate values of e T, T, and C, deduced from the experiments.

TABLE II.—*Stresses per sectional inch produced in the extreme top and bottom plates of the Conway section, from the action of the load alone (the additional stress from the action of the wind not being here included). Calculated by formula* (4) *e being taken* = 0·85.

Total distributed load in tons.	e T in tons.	T in tons.	C in tons.
Tube alone = 1112	4·488	5·280	3·717
Tube + 200 = 1312	5·295	6·229	4·386
Tube + 400 = 1512	6·102	7·179	5·054
Tube + 600 = 1712	6·909	8·128	5·723
Tube + 800 = 1912	7·716	9·078	6·391

We will suppose that the 1112 tons in the above table represent the total dead weight of the Conway tube (although it appears to be that of the bare girder alone, without allowances for permanent way, planking, roof, &c). Then the added weights will represent the movable loading: 200 tons may be taken as an actual daily test, 400 tons is the ordinary estimate of the heaviest possible load, 600 tons the same when the factor of safety for the movable load is taken equal to 1½ times that for the dead weight; 800 tons represent the same loading when the factor of safety for a movable load is taken double that for the fixed load—as at page 584 of Prof. Rankin's *Civil Engineering*.

(To be Continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

The Properties of Iron, and its Resistance to Projectiles at High Velocities. By WM. FAIRBAIRN, F.R.S. Read before the Royal Institute.

From the Lond. Civ. Eng. and Arch. Journal, August, 1862.

(Continued from p. 266).

Having ascertained, by direct experiment, the mechanical resistance of different kinds of iron and steel plates to forces tending to rupture, it is interesting to observe the close relation which exists between not only the chemical analysis as obtained by Dr. Percy, but how nearly they approximate to the force of impact, as exhibited in the experiments with ordnance at Shoeburyness.

Dr. Percy, in his analysis, observes that of all the plates tested at Shoeburyness, none have been found to resist better than those lettered A, B, C, D, with the exception of C. The iron of plate E contained less phosphorus than either of the three A, B, D; and it is clearly established that phosphorus is an impurity which tends in a remarkable degree to render the metal "cold short," *i. e.* brittle when cold.

The following table shows the chemical composition of these irons:

Mark.	Carbon.	Sulphur.	Phosphorus.	Silicon.	Manganese.
A	·01636	·104	·106	·122	·28
B	·0327	·121	·173	·160	·029
C	·023	·190	·020	·014	·100
D	·0436	·118	·228	·174	·250
E	·170	·0577	·0894	·110	·330

Comparing the chemical analysis with the mechanical properties of the irons experimented upon, we find that the presence of 0·23 per cent. of carbon causes brittleness in the iron: and this was found to be the case in the homogeneous iron plates marked C; and although it was found equal to A plates in its resistance to tension and compression, it was very inferior to the others in resisting concussion or the force of impact. It therefore follows that toughness combined with tenacity is the description of iron plate best adapted to resist shot at high velocities. It is also found that wrought iron which exhibits a fibrous fracture when broken by bending, presents a widely different aspect when suddenly snapped asunder by vibration, or a sharp blow from a shot. In the former case the fibre is elongated by bending, and becomes developed in the shape of threads as fine as silk, whilst in the latter the fibres are broken short, and exhibit a decidedly crystalline fracture. But, in fact, every description of iron is crystalline in the first instance; and these crystals, by every succeeding process of hammering, rolling, &c., become elongated, and resolve themselves into fibres. There is, therefore, a wide difference in the appearance of the fracture of iron when broken by tearing and bending, and when broken by impact, where time is not an element in the force producing rupture.

If we examine with ordinary care the state of our iron manufacture as it existed half a century ago, we shall find that our knowledge of its properties was of a very crude and most imperfect character. We have yet much to learn, but the necessities arising from our position as a nation and the changes by which we are surrounded, will stimulate our exertions to the acquisition of knowledge and the application of science to a more extended investigation of a material destined, in course of time, to become the bulwark of the nation. It is, therefore, of primary importance, that we should make ourselves thoroughly acquainted not only with the mechanical and chemical properties of iron, but that we should moreover be able to apply it in such forms and conditions as are best calculated to meet the requirements of the age in which we live.

Entertaining these views, I cheerfully commenced with my talented colleagues the laborious investigations in which we are now engaged: and looking at the results of the recent experiment with the 300-pounder gun on the one hand, and the resisting targets on the other, there is every prospect of an arduous and long-continued contest.

From the Manchester experiments to which I have alluded, we find that with plates of different thicknesses, the resistance varies directly as the thickness, that is, if the thickness be as the numbers 1, 2, 3, &c., the resistance will be as 1, 2, 3, &c.; but those obtained by impact at Shoeburyness show that, up to a certain thickness of plate, the resistance to projectiles increases nearly as the square of the thickness. That is, if the thickness be as the numbers 1, 2, 3, 4, &c., the resistance will be as the numbers 1, 4, 9, 16, &c., respectively. The measure therefore of the absolute destructive power of shot is its *vis viva*, not its momentum, as has been sometimes supposed, but the work accumulated in it varies directly as the weight of the shot multiplied into the square of the velocity.

There is therefore a great difference between statical pressure and dynamical effect; and in order to ascertain the difference between flat-ended and round-ended shot, a series of experiments were undertaken with an instrument or punch exactly similar in size and diameter, and precisely corresponding with the steel shot of the piece, ·85 diameter employed in the experiments at Shoeburyness. The results on the A, B, C, and D plates are as follows:—

Character of Plates.		Resistance in lbs.	
		Punch flat-ended.	Punch round-ended.
Half-inch thick,	A Plates, .	57,956	61,886
	B Plates, . .	57,060	48,788
	C Plates, .	71,035	85,524
	D Plates, . .	46,080	43,337
Three-quarter inch thick,	B Plates, .	84,587	98,420
	D Plates, . .	82,381	98,571
Mean, . .		67,017	72,754

These figures show that the statical resistance to punching is about the same whether the punch be flat-ended or round-ended, the mean being in the ratio of 1000 : 1085, or 8½ per cent. greater in the round ended punch. It is, however, widely different when we consider the depth of indentation of the flat-ended punch, and compare it with that produced by the round-ended one, which is 3½ times greater. Hence we derive this remarkable deduction, that whilst the statical resistance of plates to punching is nearly the same, whatever may be the form of the punch, yet the dynamic resistance or work done in punching is twice as great with a round-ended punch as with a flat-ended one. This of course only approximately expresses the true law; but it exhibits a remarkable coincidence with the results obtained by ordnance at Shoeburyness, and explains the difference which has been observed

in these experiments, more particularly in those instances where round shot was discharged from smooth-bored guns at high velocities. To show more clearly the dynamic effect or work done by the weight of shot which struck some of the targets at different velocities, the following results have been obtained:—

Target.	Weight of Shot striking Target.	Work done on Target.	
		Total.	Per square foot.
	lbs.	Foot lbs.	Foot lbs.
Thorneycroft 8-inch Shield,	1253	....	29,078,000
Thorneycroft 10-inch Embrasure,	1511	....	37,140,000
Roberts's Target, . .	946	822,000	19,726,000
Fairbairn's Target, . .	1024	324,000	23,311,000
Warrior Target, . .	3229	312,000	62,570,000
The Committee's Target, .	6410	....	124,098,780

From the above, it will be observed that the two last targets have sustained in work done what would if concentrated be sufficient to sink the largest vessel in the British navy.

We are all acquainted with the appearances and physical character of artillery, but few are conversant with the nature of the operations and the effects produced by shot on the sides of a ship or on resisting forts and targets.

The shot of a gun—to use the expression of my colleague, Mr. Pole—is simply the means of transferring mechanical power from one place to another. The gunpowder in the gun develops by its combustion a certain quantity of mechanical force, or work as it is now called, and the object of the shot is to convey this work to a distance, and apply it to an object supposed to be otherwise inaccessible. The effect of this, according to Mr. Pole's formula, is w = its velocity in feet per second; v = weight of the shot in pounds. Then, by the principle of *vis viva*, the quantity of work stored up by the moving mass, measured in lbs. 1 foot high is $= \frac{w\,v^2}{2\,g}$, g being the force of gravity $= 32\frac{1}{6}$.

Thus, if we have a shot, like that recently used against the *Warrior* target, 156 lbs., moving at the rate of 1700 feet per second, the work done will be $= \frac{156 \div (1700)^2}{64\frac{1}{3}} = 7{,}008{,}238$ one foot high.

Showing at once the immense power that this small body is able to deliver on every resisting medium tending to arrest its course and bring its particles to a state of rest; or in other words, it is equivalent to raising upwards of 3000 tons a foot high in the air.

The application of Iron for purposes of Defence.—Having examined, in a very condensed and cursory manner, the present state of our knowledge in regard to iron, and its application to the purposes of ship-building, let us now consider in what form and under what circumstances it can best be applied for the security of our vessels and

forts. To the latter the answer is, make the battery shields thick enough; but a very different solution is required for the navy, where the weight and thickness of the plates is limited to the carrying powers of the ship. It has been observed with some truth, that we have learnt a lesson from the recent naval action on the American waters; but it must be borne in mind that neither of the vessels engaged nor the ordnance employed were at all comparable to what have been used at Shoeburyness.

To those who, like myself, have gone through the whole series of experiments, the late engagement will appear instructive, but not calculated to cause any great alarm, nor yet effect any other changes than those primarily contemplated by the Government, and such as have been deduced from our own experiments. It is, nevertheless, quite evident that our future navy *must be entirely of iron;* and judging from the last experiment with the Armstrong smooth-bore gun, it would almost appear as a problem yet to be solved, whether our ships of war are not as safe without iron armor as with it. If our new construction of ships are strong enough to carry armaments of 300-pounder guns, which is assumed to be the case, our plating of 6 or 7 inches thick would be penetrated, and probably become more destructive to those on board than if left to make a free passage through the ship. In this case we should be exactly in the same position as we were in former days with the wooden walls; but with this difference, that if built of iron the ship would not take fire, and might be made shell-proof. It is, however, very different with forts, where weight is not a consideration, and those I am persuaded may be made sufficiently strong to resist the heaviest ordnance that can be brought to bear against them. In this statement I do not mean to say that ships of war should not be protected; but we have yet to learn in what form this protection can be effected to resist the last powerful ordnance, and others of still greater force which are *looming in the distance*, and are sure to follow.

A great outcry has been raised about the inutility of forts; and the Government, in compliance with the general wish, has suspended those at Spithead,—I think improperly so, as the recent experiments at Shoeburyness clearly demonstrate that no vessel, however well protected by armor-plates, could resist the effects of such powerful artillery; and instead of the contest between the *Merrimac* and the *Monitor*, and that of the 300-pounder gun, being against, they are to every appearance in favor of forts. Should this be correct, we have now to consider how we are to meet and how resist the smashing force of such powerful ordnance as was levelled against the Warrior target.

During the whole of the experiments at Shoeburyness, I have most intently watched the effects of shot on iron plates. Every description of form and quality of iron has been tried, and the results are still far from satisfactory; and this is the more apparent since the introduction of the large 300-pounder, just at a time when our previous experiments were fairly on the balance with the 40, 68, 100, and 126 pounders. They now appear worthless, and nothing is left but to begin our labors again *de novo*.

It has been a question of great importance, after having determined the law of resistance and the requisite quality of the iron to be used as armor-plates, how these plates should be supported and attached to the sides of the ship. Great difference of opinion continues to exist on this subject; some are for entirely dispensing with wood; probably the greater number contend for a wood backing, the same as the *Warrior* and the *Black Prince*. I confess myself in the minority on this question; and, judging from the experiments, I am inclined to believe from past experience that wood combined with iron is inferior to iron and iron in its power of resistance to shot; and I am fully persuaded that ultimately the iron armor-plates must be firmly attached to the sides, technically called the skin, of the ship. It must, moreover, form part of the ship itself, and be so arranged and jointed as to give security and stability to the structure.

The experiments instituted by the Committee on Iron Plates have been well considered and carefully conducted; they commenced with a series of plates selected from different makers, of varying thicknesses, and these have been tested both as regards quality and their powers of resistance to shot. They have, moreover, been placed at different angles and in a variety of positions; and we had just arrived at the desired point of security when the thundering 300-pounder smooth-bore upset our calculations, and leveled the whole fabric with the ground. We are, however, not yet defeated; and true to the national character, we shall, like the knights of old, resist to the last—

> "And though our legs are smitten off,
> We'll fight upon our stumps."

And thus it will be with the Iron Committee and the Armstrong and the Whitworth guns.

In conclusion, allow me to direct attention to a drawing of the Warrior target with wood backing, and its compeer entirely of iron. The first underwent a severe battering previous to the attack from the 300-pounder, but the other sustained still greater with less injury to the plates, notwithstanding the failure of the bolts in the first experiment. It must however be admitted, that plates on wood backing have certain advantages in softening the blow, but this is done at the expense of the plate, which is much more deflected and driven into the wood, which from its compressibility presents a feeble support to the force of impact. Again, with wood intervening between the ship and the iron plates, it is impossible to unite them with long bolts so as to impart additional strength to it; on the contrary, they hang as a dead weight on her sides, with a constant tendency to tear her to pieces. Now, with iron on iron we arrive at very different and superior results. In the latter, the armor-plates if properly applied will constitute the strength and safety of the structure; and, notwithstanding the increased vibration arising from the force of impact of heavy shot, we are more secure in the invulnerability of the plates, and the superior resistance which they present to the attack of the enemy's gun. In these remarks I must not, however, attempt to defend iron constructions where they are not defensible, and I am bound to state that in

constructions exclusively of iron there is a source of danger which it is only fair to notice, and that is, that the result of two or more heavy shot or a well concentrated fire might not only penetrate the plates, but break the ribs of the ship. This occurred in the last experiment on my own target, where a salvo of six guns concentrated four on one spot, not more than 14 inches diameter, went through the plates and carried away a part of the frame behind. The same effect might have taken place on the Warrior target; and certainly 9 ins. of wood is of little value when assailed by a powerful battery of heavy ordnance and a well concentrated fire.*

In closing these remarks, I have every confidence that the skill and energy of this country will keep us in advance of all competitors, and that a few more years will exhibit to the world the iron navy of England, as of old with its wooden walls, unconquerable on every sea.

* Since the above was written, another experiment has been made on the Warrior target with the 300-pounder smooth-bore gun. From this it appears that the wood backing between the armor-plates and the skin of the ship cannot safely be dispensed with, and that some compressible or softer substance than iron and iron is necessary to deaden the blow, and absorb the fragments of the shot and the broken plates, which in this instance lodged in the wood, and did not perforate, but only cracked the skin of the target. From this fact it cannot be denied that this experiment is more satisfactory than those on the iron on iron targets; and however desirable it may be to realize a more effective construction as regards the strength of the ship, it cannot be doubted, in so far as the security of the ship and the lives of those on board are concerned, that a vessel with wood backing is safer in action than one composed entirely of iron. In the present state of our knowledge, the experiments are therefore against iron and iron, as regards security from the effects of shot, but they are unfavorable as respects the strength of the ship.

Hydraulic Presses.

From the London Artizan, August, 1862.

For many purposes for which presses are employed, such for example as for packing cotton and other fibres, and similar materials, the press is required during a considerable portion of its stroke to exert but a comparatively small pressure, whilst for the latter portion of the stroke a much heavier pressure is required. Mr. M. Scott, of Parliament Street, proposes to employ a compound press, consisting of two or more concentric cylinders. The innermost is fitted with a ram like an ordinary hydraulic press, the cylinder is closed at the bottom, and is made itself to serve as the ram of another hydraulic press formed with the next concentric cylinder, and this may in turn form the ram of a third press. When the press is set to work the water from a force-pump or accumulator is directed first into the interior cylinder, and as this is of small diameter the ram thereof rapidly rises, but the pressure will be comparatively light. As soon as this pressure proves insufficient, a cock placed on the supply-pipe of the inner cylinder is closed, and another cock is opened, so as to admit the water from the force-pump or accumulator to the second cylinder. In this manner the ram of the second press, which is the cylinder of the first, is raised, carrying its own ram with it, this being unable to descend, being blocked by the water enclosed beneath it. When the second cylinder is brought into work, the action of the press will be slower, and the force exerted will be greater, in proportion as the sectional area of the ram of the second press (or the cylinder of the first) exceeds the sectional area of the ram of the first press. When a third cylinder is employed it is brought into action after the second in a similar man-

ner, the second press being then in turn blocked by the water enclosed in it. The important feature in the invention is the blocking of one press, whilst a more powerful one is caused to act against it thus:—Two separate hydraulic presses, the one of small, and the other of large power, may be arranged one at each end of a frame, the material to be pressed between them is received between the two presses, and is partly compressed by the press of smaller power; then this is blocked by enclosing water in it, and the press of greater power is put in action to complete the compression. This arrangement may also be employed where mechanical blocking is used in place of or together with water blocking.

New Manufacture of Gunpowder.

From the London Artizan, August, 1862.

Mr. W. Bennetts, of Tuckingmill, has invented a new method of manufacturing gunpowder, the ingredients consisting of lime, nitre, sulphur, and charcoal; the lime is dissolved in a sufficient quantity of water to bring the other elements into a paste. The lime after having been made into a solution is strained through a fine sieve; this solution is then added to the other ingredients, and the whole is put into a mill and ground until it becomes a paste; it is then taken out of the mill and passed between two rollers, one grooved and the other plain. The paste by passing between the rollers is formed into long strips of a triangular shape; it is then carried on an endless web or canvass over some hot tubes, which are heated by steam, hot water, or any other artificial heat which may be applied; by this means the strips are easily broken into grains. This mode of manufacture prevents a great deal of danger, as the powder is pulverized and brought into grain while in a wet state. The lime makes a firm grain, resists the damp, and gives it a degree of lightness which increases the bulk 25 per cent. over ordinary gunpowder—a great advantage for blasting purposes. Plaster of paris, blue lias, Roman or Portland cement, or other strong cementing substance, may be used as a substitute for lime. And the patentee finds that for blasting purposes the following proportions answer well—that is to say, nitre, 65 lbs.; charcoal, 18 lbs.; sulphur, 10 lbs.; and lime, 7 lbs.; but the proportions may be varied according to the strength required.

Safety-Valves of Steam Boilers.

At a meeting of the Academy of Sciences of Vienna, M. de Burg gave an account of his experiments on the mode of action of the safety-valves of steam boilers. These results are in contradiction with the theoretical propositions upon which the regulations for the dimensions of these boilers have been based: inasmuch as in reality these valves do not rise to a height equal to one-fourth of their diameter, that is, one or more inches, but only so as to leave a passage for the steam whose diameter does not exceed the fraction of a line. These appara-

tus therefore cannot fulfil their object, which is to give simultaneous issue to all the steam which a boiler can produce when it has reached a determinate degree of tension, and thus to prevent all danger of explosion. To fulfil this purpose they ought to be at least six times, and in some cases twenty times larger than the rules prescribe.

L'Institut.

Durability of Cast Iron in Sea Water. By E. B. Webb, M. Inst. C. E., &c.

From the Lond. Civ. Eng. and Arch. Jour., Aug., 1862.

Mr. Webb has given special attention to the durability of cast iron in sea water, and the subject is one of such importance that we extract his observations; while not professing to show that all cast iron may be trusted to withstand the deteriorating action of the sea, our author brings forward several instances in which its judicious employment has been proved by its remaining uninjured after many years submersion.

Cast iron in sea water is liable to two descriptions of deterioration, generally by the absorption of oxygen, and occasionally, with certain qualities of metal, by a softening of the outer surface.

The oxidation of cast iron in sea water does not proceed rapidly, even when its surface is unprotected and its quality that most favorable for a union with oxygen. An idea of the rate of oxidation may be formed from the following statement by Mr. R. Mallet (as the result of numerous experiments), that "cast iron freely exposed to the weather at Dublin, and to all its atmospheric precipitations, was corroded nearly as fast as if in clear sea water, when the specimens in both cases were wholly unprotected."

In iron breakwaters, the question as to durability will refer chiefly to the parts below low water; for the protection of the superstructure against slow and unimportant oxidation may be readily insured. It has been stated, that the oxidation of iron surfaces continually covered with water goes on more slowly than when the metal is exposed alternately to air and water. In addition to this circumstance, favorable to the easy protection of ironwork standing in the sea, it will be found that in the majority of localities the sea itself provides, in the shape of mollusks, an excellent protection to the submerged portions.

The softening of cast iron is a process not clearly understood. Cast iron will soften in the cylinders and pipes used in mines, as well as in piles standing in sea water. After softening under sea water it will at times become hard again on exposure to the air. Cast iron, however, is very far from being generally liable to the process of softening.

In consequence of the great variety in the quality of cast iron, instances are not wanting which apparently support directly opposite opinions. Cast iron has been taken up after immersion in sea water, utterly decomposed. In many such cases, it is known that the iron has been purposely cast of the softest metal, and in others it may airly be presumed that soft metal has been employed. On the other

hand, there are numerous instances of cast iron having remained perfectly sound and uninjured after an immersion for many years in sea water. From very numerous examples of long immersion without injury, the writer will select a few which he has personally examined.

Dock Gates, Sheerness.—There are several pairs of cast iron dock gates at Her Majesty's dock-yard, Sheerness. They were designed by the late Mr. Rennie. The heel posts, mitre posts, and ribs, are of cast iron. The gates are sheeted from top to bottom with cast iron plates, perfectly water-tight. Three pairs of gates have been exposed to the action of sea water since 1821, and a fourth pair since 1827.

The writer examined these gates in January of this year, 1862, and he found that the framing and plates were in perfect condition. From the dock-yard officials he learnt that no portion of the cast iron had ever been replaced, in consequence of deterioration of the metal, and that no plate had given way, although there is a head of water equal to 26 feet at spring tides. Three pairs of these gates have, therefore, resisted the action of sea water, uninjured, for fully forty years, and a fourth pair for thirty-five years.

The writer observed, however, that the cast iron sector plates, against which the gates shut, are softened in places to some little extent, but only where the iron is in contact with a mass of lead, which has been used to form a water-tight joint; the galvanic action created by the contact of the two metals having, doubtless, caused the softening of the iron.

At Chatham, the writer saw a number of iron castings which had been removed thither from a dock at Pembroke, where a caisson has replaced the gates. After an immersion in sea water at Pembroke for many years, these castings are found to be in so perfect a state, that they will shortly be put in use at the new entrance to No. 1 dock at Chatham, there again to be exposed to the action of sea water.

Lowestoft Harbor (*Basin Entrance*).—The late Sir W. Cubitt having witnessed the rapid destruction of timber in the sea at Lowestoft, and being satisfied as to the durability of cast iron in sea water, determined upon casing the entrance of the Lowestoft basin with cast iron piles. The work was commenced in 1832, under Mr. George Edwards. The writer examined these piles last year, and he found them uninjured. They are, for all practical purposes, as sound and as perfect as when they were driven—upwards of 28 years ago.

Southend Pier (*Extension*).—Mr. Jas. Simpson (Past-President of the Institution of Civil Engineers), in designing the extension of this pier, after careful consideration of the durability of cast iron in sea water, selected that metal for his piles. The extension was executed in 1844. In February, last year, the writer examined these piles; he found them in a most perfect state. They are square, and the angles are as sharp as when they left the foundry. Mr. Simpson specified the quality of the iron from which these piles were to be cast, because he found, from examination of specimens of cast iron which had been exposed to the action of sea water, that the durability depended upon the quality. These piles, after having been exposed to sea water during 17 years, are perfectly uninjured.

Herne Bay Pier.—The pier at Herne Bay, nearly three-quarters of a mile in length, was designed by the late Mr. Telford. It was built of timber in 1831. After standing for about seven years, the piles were generally so far destroyed by the worm, that it was decided to use cast iron, to a great extent, in the repairs. Accordingly, in 1838, a great number of cast iron square piles were driven. Very recently the writer examined this pier. He found the cast iron in a most perfect state. The angles of the piles were sharp, and the surface as smooth and as sound as when the castings left the foundry. The piles, as usual, are covered with shell-fish, which keep the surfaces moist during ebb tide. Not more than one-half of the whole piles in the pier are of iron; those of wood are either cut through by the worm, or are under that process of destruction. The timber piles have required constant repairs and renewals. Upon the cast iron not a shilling has been expended. The pier, in consequence of the destruction of the timber, which is immersed in the sea, is in a most dangerous condition. Had Mr. Telford, in the first instance, selected cast iron for the piles of his pier, the substructure would have been as sound to-day as when put down in 1831. With the exception of the cast iron piling, which has been under the action of sea water 23 years uninjured, this pier may now be termed a ruin.

Margate Jetty.—A jetty erected at Margate in 1831 rested on timber supports fitted into cast iron piles. These piles did not stand sufficiently high from the bed of the sea, and the lower portion of the timber, exposed to sea water, was destroyed by the worm. In 1853, nearly all of them were taken up and sold for old metal at the price of pig iron; and in the same year, a new iron pier, resting on cast iron piles, was erected by Messrs. J. B. and E. Birch. A number of the old piles, after having been immersed in the sea water for upwards of 20 years, were last year to be seen on the pier at Margate. The writer has carefully examined them; they are as sound as when they left the foundry; in no instande can any softening of the metal be detected. A still stronger proof, however, is to be found in some of the cast iron piles of the old jetty, which are still *in situ* at the head of the present jetty. In these piles no deterioration whatever can be discovered. The shell-fish with which they are covered form a perfect protection against oxidation. These piles have stood in the sea during 30 years, and are perfectly uninjured.

If, then, numerous and undoubted examples of cast iron do exist which have withstood the action of sea water, without any deterioration, for upwards of a quarter of a century, we must come to the conclusion, that where cast iron has been injured or decomposed in open sea water within a less period, the cause is to be found chiefly in the quality of the iron not being suitable for the work in which it is placed. The power, therefore, of various classes of cast iron to resist the action of sea water, will vary according to quality.

The cast iron used by Mr. Murray in the dock gates of Sunderland may be cited in proof of the foregoing statement. After an immersion for some years, the rollers under the gates were found to have been

acted upon by sea water, but other portions of cast iron placed in the body of the gates remained uninjured. As the rollers had to be turned in the lathe, they were doubtless cast of soft material, but the other portions of cast iron, not requiring to be cut by tools, were of harder metal. The former gave way, but the latter remained perfect.

The words *cast iron* admit of almost the same latitude of signification as the word *timber*. Because we dare not use poplar on account of its liability to decay, it does not follow that no structures are to be erected of other qualities of wood.

At a meeting of the Institution of Civil Engineers (February 13th, 1844), Mr. J. Simpson stated, that with good grey cast iron, having a good surface, little injurious effect from the sea water was to be dreaded. He also stated that he was then about to use cast iron extensively for piles, and that he had examined cast iron piles which had been in sea water for 16 years without any detrimental effect being produced.

It appears that the action of sea water is powerful in the greatest degree when the iron is composed of large crystals, and especially when there is irregularity in the crystallization. It may be said that the softer the iron the greater is the liability to decomposition.* Between the limits of extreme softness and decay on the one hand, and extreme hardness and durability, with brittleness, on the other, we have to make the selection. It has been stated† that chilled cast iron corrodes faster than green sand castings, that all castings intended for use in sea water should be cooled in the sand to insure uniformity in the crystals, and that Welsh iron is the best. From a careful investigation of the subject, the writer has arrived at the conclusion, that a strong description of cast iron may be employed, capable of enduring the action of sea water for an indefinite length of time.

In cases where, from the use of an unsuitable quality of iron, or from contact with some other metal (such as lead or copper), softening of the iron has taken place, it will generally be found that the glazed skin produced by the sand of the mould in the process of casting, has been removed by tools, accident, or wear. An iron breakwater can be erected without any removal of this protecting glazed skin; no holes will be required to be bored, and no surfaces cut by tools.

As an instance of the detrimental effect of placing another metal in contact with cast iron, it may be stated that the cast iron plates affixed to ships bottoms (according to the proposition of Sir H. Davy) for the protection of the copper sheathing, rapidly became softened.

* In Brande's Manual of Chemistry, (vol. i. p. 754, edition 1848,) the following remarks are made upon cast iron:—"White cast iron is very hard, and when broken, of a radiated texture. Acids act upon it but slowly, and exhibit a texture composed of a congeries of plates, aggregated in various positions. Grey or mottled cast iron is softer and less brittle; it may be bored and turned in the lathe. When immersed in dilute hydrochloric acid, it affords a large quantity of black insoluble matter, which Daniell considers as a triple compound of carbon, iron, and silicium, and which has some very singular properties. The texture of the metal resembles bundles of minute needles."

In a paper inserted in the "Edinburgh Philosophical Journal," (vol. vii. p. 201,) Dr. McCulloch remarks, that "the blackest pig-metal appears to yield the greatest quantity of black-lead, and in the most solid state."

The "Mining Journal," of January 11th, 1862, under the head of "Artificial Plumbago," states, that "for some time past, Dr. Crace Calvert, F.R.S., has been engaged in experimenting upon the composition of a carboniferous substance existing in grey cast iron, or, to use a more popular definition, in producing plumbago from cast iron. The effect of his experiments has been to arrive at results which throw much light upon the chemical composition of the substance, proving it to be composed of iron, carbon, nitrogen, and silicium."

† Minutes of Proceedings, Institution of Civil Engineers, vol. i. p. 72 (Session 1840).

Lecture on Force. By Prof. TYNDALL, at the Royal Institution.

From the London Mechanics' Magazine, July, 1862.

(Continued from page 271.)

There is one other consideration connected with the permanence of our present terrestrial conditions, which is well worthy of our attention. Standing upon one of the London bridges, we observe the current of the Thames reversed, and the water poured upwards twice a day. The water thus moved rubs against the river's bed and sides, and heat is the consequence of this friction. The heat thus generated is in part radiated into space, and then lost, as far as the earth is concerned. What is it that supplies this incessant loss? The earth's rotation. Let us look a little more closely at the matter. Imagine the moon fixed, and the earth turning like a wheel from west to east in its diurnal rotation. Suppose a high mountain on the earth's surface; on approaching the moon's meridian, that mountain is, as it were, laid hold of by the moon, and forms a kind of handle by which the earth is pulled more quickly round. But when the meridian is passed, the pull of the moon on the mountain would be in the opposite direction—it now tends to diminish the velocity of rotation as much as it previously augmented it; and thus the action of all fixed bodies on the earth's surface is neutralized. But suppose the mountain to lie always to the east of the moon's meridian, the pull then would be always exerted against the earth's rotation, the velocity of which would be diminished in a degree corresponding to the strength of the pull. *The tidal-wave occupies this position*—it lies always to the east of the moon's meridian, and thus the waters of the ocean are in part dragged as a brake along the surface of the earth; and as a brake they must diminish the velocity of the earth's rotation. The diminution, though inevitable, is, however, too small to make itself felt within the period over which observations on the subject extend. Supposing then that we turn a mill by the action of the tide, and produce heat by the friction of the mill-stones; that heat has an origin totally different from the heat produced by another mill which is turned by a mountain stream. The former is produced at the expense of the earth's rotation, the latter at the expense of the sun's radiation.

The sun, by the act of vaporization, lifts mechanically all the moisture of our air. It condenses and falls in the form of rain—it freezes and falls as snow. In this solid form it is piled upon the Alpine heights, and furnishes materials for the glaciers of the Alps. But the sun again interposes, liberates the solidified liquid, and permits it to roll by gravity to the sea. The mechanical force of every river in the world, as it rolls toward the ocean, is drawn from the heat of the sun. No streamlet glides to a lower level without having been first lifted to the elevation from which it springs by the mighty power of the sun. The energy of winds is also due entirely to the sun; but there is still another work which he performs, and his connexion with which is not so obvious. Trees and vegetables grow upon the earth, and when burned they give rise to heat, and hence to mechanical energy. Whence is this power

derived? You see this oxide of iron, produced by the falling together of the atoms of iron and oxygen; here also is a transparent gas which you cannot now see—carbonic acid gas—which is formed by the falling together of carbon and oxygen. These atoms thus in close union resemble our lead weight while resting on the earth; but I can wind up the weight and prepare it for another fall, and so these atoms can be wound up, separated from each other, and thus enabled to repeat the process of combination. In the building of plants, carbonic acid is the material from which the carbon of the plant is derived; and the solar beam is the agent which tears the atoms asunder, setting the oxygen free, and allowing the carbon to aggregate in woody fibre. Let the solar rays fall upon a surface of sand; the sand is heated, and finally radiates away as much heat as it receives; let the same beams fall upon a forest, the quantity of heat given back is less than the forest receives, for the energy of a portion of the sunbeams is invested in building up the trees in the manner indicated. Without the sun the reduction of the carbonic acid cannot be effected, and an amount of sunlight is consumed exactly equivalent to the molecular work done. Thus trees are formed; thus the cotton on which Mr. Bazley discoursed last Friday is formed. I ignite this cotton, and it flames: the oxygen again unites with its beloved carbon; but an amount of heat equal to that which you see produced by its combustion was sacrificed by the sun to form that bit of cotton.

But we cannot stop at vegetable life, for this is the source, mediate or immediate, of all animal life. The sun severs the carbon from its oxygen; the animal consumes the vegetable thus formed, and in its arteries a reunion of the several elements takes place, and produces animal heat. Thus, strictly speaking, the process of building a vegetable is one of winding up; the process of building an animal is one of running down. The warmth of our bodies, and every mechanical energy which we exert, trace their lineage directly to the sun. The fight of a pair of pugilists, the motion of an army, or the lifting of his own body up mountain slopes by an Alpine climber, are all cases of mechanical energy drawn from the sun. Not, therefore, in a poetical, but in a purely mechanical sense, are we children of the sun. Without food, we should soon oxidize our own bodies. A man weighing 150 lbs. has 64 lbs. of muscle; but these, when dried, reduce themselves to 15 lbs. Doing an ordinary day's work for 80 days, this mass of muscle would be wholly oxidized. Special organs which do more work would be more quickly oxidized: the heart, for example, if entirely unsustained, would be oxidized in about a week. Take the amount of heat due to the direct oxidation of a given amount of food; a less amount of heat is developed by this food in the working animal frame, and the missing quantity is the exact equivalent of the mechanical work which the body accomplishes.

I might extend these considerations—the work, indeed, is done to my hand—but I am warned that I have kept you already too long. To whom, then, are we indebted for the striking generalizations of this evening's discourse? All that I have laid before you is the work

of a man of whom you have scarcely ever heard. All that I have brought before you has been taken from the labors of a German physician, named Mayer. Without external stimulus, and pursuing his profession as town physician in Heilbronn, this man was the first to raise the conception of the interaction of natural forces to clearness in his own mind. And yet he is scarcely ever heard of in scientific lectures, and even to scientific men his merits are but partially known. Led by his own beautiful researches, and quite independent of Mayer, Mr. Joule published his first paper on the "Mechanical Value of Heat" in 1843; but in 1842 Mayer had actually calculated the mechanical equivalent of heat from data which a man of rare originality alone could turn to account. From the velocity of sound in air Mayer determined the mechanical equivalent of heat. In 1845 he published his Memoir on "Organic Motion," and applied the mechanical theory of heat in the most fearless and precise manner to vital processes. He also embraced the other natural agents in his chain of conservation. In 1853 Mr. Waterston proposed, independently, the meteoric theory of the sun's heat, and in 1854 Professor William Thomson applied his admirable mathematical powers to the development of the theory; but six years previously the subject had been handled in a masterly manner by Mayer, and all that I have said on this subject has been derived from him. When we consider the circumstances of Mayer's life, and the period at which he wrote, we cannot fail to be struck with astonishment at what he has accomplished. Here was a man of genius working in silence, animated solely by a love of his subject, and arriving at the most important results some time in advance of those whose lives were entirely devoted to Natural Philosophy. It was the accident of bleeding a feverish patient at Java in 1840 that led Mayer to speculate on these subjects. He noticed that the venous blood in the tropics was of a much brighter red than in colder latitudes, and his reasoning on this fact led him into the laboratory of natural forces, where he has worked with such signal ability and success. Well, you will desire to know what has become of this man. His mind gave way; he became insane, and he was sent to a lunatic asylum. In a biographical dictionary of his country it is stated that he died there; but this is incorrect. He recovered, and, I believe, is at this moment a cultivator of vineyards in Heilbronn.

JUNE 20.

While preparing for publication my last course of lectures on Heat, I wished to make myself acquainted with all that Mayer had done in connexion with this subject. I accordingly wrote to two gentlemen who above all others seemed likely to give me the information which I needed. Both of them are Germans, and both particularly distinguished in connexion with the Dynamical Theory of Heat. Each of them kindly furnished me with the list of Mayer's publications, and one of them was so friendly as to order them from a bookseller, and to send them to me. This friend, in his reply to my first letter regarding Mayer, stated his belief that I should not find anything very important in Mayer's writings; but before forwarding the Memoirs to me he

read them himself. His letter accompanying the first of these papers contains the following words:—"I must here retract the statement in my last letter, that you would not find much matter of importance in Mayer's writings; I am astonished at the multitude of beautiful and correct thoughts which they contain;" and he goes on to point out various important subjects, in the treatment of which Mayer had anticipated other eminent writers. My second friend, in whose own publications the name of Mayer repeatedly occurs, and whose papers containing these references were translated some years ago by myself, was, on the 10th of last month, unacquainted with the thoughtful and beautiful essay of Mayer's, entitled "Beiträge zur Dynamik des Himmels;" and in 1854, when Professor William Thomson developed in so striking a manner the meteoric theory of the sun's heat, he was certainly not aware of the existence of that Essay, though from a recent article in "Macmillan's Magazine" I infer that he is now aware of it. Mayer's physiological writings have been referred to by physiologists—by Dr. Carpenter, for example—in terms of honorable recognition. We have hitherto, indeed, obtained fragmentary glimpses of the man, partly from physicists and partly from physiologists; but his total merit has never yet been recognised as it assuredly would have been had he chosen a happier mode of publication. I do not think a greater disservice could be done to a man of science than to overstate his claims: such overstatement is sure to recoil to the disadvantage of him in whose interest it is made. But when Mayer's opportunities, achievements, and fate are taken into account, I do not think that I shall be deeply blamed for attempting to place him in that honorable position which I believe to be his due.

Here, however, are the titles of Mayer's papers, the perusal of which will correct any error of judgment into which I may have fallen regarding their author: "Bemerkungen über die Kräfte der unbelebten Natur," Liebig's Annalen, 1842, vol. xlii. p. 231; "Die Organische Bewegung in ihrem Zusammenhange mit dem Stoff-wechsel," Heilbronn, 1845; "Beiträge zur Dynamik des Himmels," Heilbronn, 1848; "Bemerkungen über das Mechanische Equivalent der Wärme," Heilbronn, 1851. J. T.

The Melting of Steel.

M. Alfred Sudre having proposed a new mode of melting large masses of steel in a reverberatory furnace, his majesty the Emperor directed experiments to be made on a large scale at his own expense, under the direction of a committee composed of MM. Treuille, Colonel of Artillery and Director of the *atelier de precision* of Paris; Caron, Captain of Artillery, Chief of the Chemical works of the same establishment, and H. Sainte-Claire Deville, of the Normal School. These experiments were executed under the eyes of this committee, who have established the favorable results in a report to his majesty, which we thus condense:

Attempts have been for a long time made to melt steel in a rever-

beratory furnace; probably there is not a manufacturer of steel who has not at least once in his life tried an experiment of this kind. Up to this time every one has failed, owing to the almost immediate destruction of the furnace.

M. Sudre saw that this destruction was caused by the formation of an oxide of iron by the flame in direct contact with the steel, which oxide combined with the silica of the bricks of the furnace, producing a very fusible silicate of iron, and thus melting down the furnace at the same time with the steel.

His problem then was to prevent the steel from contact with the air by the interposition of a slag which should not alter either the steel or the furnace-walls. This he solved by the employment of bottle glass or the slag of a charcoal smelting-furnace.

The committee establish:

1st. That under this slag, the steel melts easily and rapidly without losing any of its qualities.

2d. That by this mode 2000 kilogrammes (2 tons) of steel may be melted at once in the same furnace.

3d. That in the present state of things, and notwithstanding certain imperfections in the experimental furnace, there is a remarkable economy, as well from the omission of the crucibles as from the want of less fuel for a given quantity of steel.

4th. That furnaces constructed of fire-bricks resist only moderately well, in consequence of the number of joints, and that there would be an advantage in making the hearths and arches either of one piece or of a number of pieces grooved together as in the hearths of copper-furnaces. *Cosmos.*

The Great Foucault Telescope.

From the London Intellectual Observer, June, 1862.

M. Léon Foucault has laid before the French Academy an account of the great telescope constructed upon his principle for the Observatory at Paris. He observes that his efforts to obtain large instruments with reflectors of silvered glass could not be deemed completely successful until he had reached dimensions exceeding those of the largest achromatic objectives, and that it was only by way of establishing a claim to the recognition of his plans that he announced the formation of mirrors of 10, 20, and 40 centimetres in diameter. Now, he is able to speak of one nearly 80 centimetres in diameter, having a focal length of 4½ metres,* which has been completed in the establishment of M. Secrétan. This mirror, mounted in a Newtonian telescope, has been at work for three months at the Observatory, performing to the entire satisfaction of the director, M. Chacornac.

The thick glass disk was cast in a curved form (*bombé*), at the factory of St. Gobain, in a mould prepared by M. Sautter, the director of the works for the lenticular lighthouse apparatus, and although possessing sufficient homogeneity for its intended purpose, showed

* The metre is 39·3779 inches; the centimetre 0·3937 of an inch.

before it was silvered that a flaw had occurred during the process of cooling. On its arrival at M. Sautter's workshops, it was reduced in dimensions by bringing it nearer to the required shape, and by cutting a groove to fix the mechanism necessary for its manipulation. It then passed into the hands of M. Secrétan's skilful operatives, who ground it with a counter piece of glass, 50 centimetres in diameter, assisted by emery and water. This process, which was frequently tested by the spherometer, occupied a week, at the end of which time a fine grained and exactly spherical surface was obtained. Having been thus prepared, it was polished by hand, the polisher employed being 22 centimetres in diameter, and covered with rouge. This polishing was completed by one able workman in another week, and the mirror was changed from the spherical to the paraboloid form. From this moment its success appeared certain, and it was removed, with the necessary tools, to the Observatory, to be optically tested, and to receive the finishing touches.

The frame and stand were made by M. Eichens, the director of M. Secrétan's works. The telescope is suspended from its centre of gravity by two trunnions, resting on two solid vertical columns. It possesses vertical and azimuthical movements, so that it only requires to have its inclination adjusted to the latitude of the place in which it may finally rest, to constitute a veritable equatorial. In consequence of the complaints made by the French astronomers of the unfavorable atmosphere of Paris, the new telescope will be placed in an observatory to be erected in the south, and specially devoted to original investigations.

On the 28th ult., M. Le Verrier exhibited to the Academy a drawing representing the double nebula in Canes Venatici—the wonderful spiral formation of which was made known through the magnificent instrument at Parsonstown—as seen by the Foucault mirror. The Abbé Moigno tells us that the drawing exhibits "incomparably more details than those given by Herschel and Lord Rosse." If this be correct, the Foucault telegraph must possess an enormous advantage over the old form of reflectors, as the diameter of the new instrument is less than half that at Parsonstown.

We understand that four-inch instruments of this description, in a square mahogany frame, elevated or depressed by a rack movement like that of a reading desk, may be had in Paris for £10. They are, however, liable to become tarnished, when they need an inexpensive process of repair.

New Regulator for Temperatures.

A committee of the French Academy of Sciences reports very favorably of a new automatic temperature-regulator which M. Eugene Rollaud has attached to his Mechanical Roaster, and which, the committee say, has worked for eight years with the precision of a piece of physical apparatus and the certainty of a practical machine.

The combustion of the furnace is regulated by balance valves on the

pipes through which the air is introduced, which valves are automatically governed by the regulator. This regulator consists of a mercury gauge, the closed branch of which is attached to a fixed support, while the cistern is freely suspended to the beam of a balance; the varying weight in this branch will cause the beam to assume different positions depending on the temperature of the apparatus, which variation of position may be used to govern the valve. In order to prevent the barometric changes from affecting the apparatus, the closed end of a syphon barometer whose tube is of the same diameter with the gauge, is attached to the beam, while its cistern is sustained by the fixed support. The barometric changes will then affect these two instruments equally and in opposite directions, and will consequently have no effect on the position of the balance beam.—*Comptes Rendus of the Academy of Sciences*, July, 1862.

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillars: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, Civ. Eng.

(Continued from page 123.)

Solid Uniform Square Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Side of the square in inches.	Number of diameters contained in the length or height.	Value of w in tons from formula $w = 10{\cdot}95\ \frac{D^4}{l^2}$	Value of c	Calculated breaking weight in tons from formula $Y = \frac{wc}{w + lc}$.	Strength per sq. inch of section in tons.
8	9	10⅔	1122·54	279·53	235·54	2·90
9	"	12	886·95	"	226·09	2·79
10	"	13⅓	718·42	"	216·38	2·67
11	"	14⅔	593·74	"	206·58	2·55
12	"	16	498·90	"	196·82	2·43
13	"	17⅓	425·10	"	187·20	2·31
14	"	18⅔	366·54	"	177·82	2·19
15	"	20	319·30	"	168·74	2·08
16	"	21⅓	280·63	"	160·00	1·97
17	"	22⅔	248·59	"	151·64	1·87
18	"	24	221·73	"	143·68	1·77
19	"	25⅓	199·01	"	136·12	1·68
20	"	26⅔	179·60	"	128·97	1·59
21	"	28	162·90	"	122·22	1·50
22	"	29⅓	148·43	"	115·87	1·43
23	"	30⅔	135·80	"	109·88	1·35
24	"	32	124·72	"	104·26	1·28
25	"	33⅓	114·94	"	98·98	1·22
26	"	34⅔	106·27	"	94·03	1·16
27	"	36	98·55	"	89·38	1·10
28	"	37⅓	91·63	"	85·01	1·04
29	"	38⅔	85·42	"	80·92	0·99
30	"	40	79·82	"	77·08	0·95

Solid Uniform Square Pillars of Red Deal, Both Ends being Flat and Firmly Fixed,

Length or height of Pillar in feet.	Side of the square in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula $w = 7{\cdot}81\frac{D^4}{L^2}$.	Value of w in tons from formula $w = 7{\cdot}81\frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula $r = \frac{wc}{w+4c}$.	Strength per sq. inch of section in tons.
8	9	10⅔		800·64	238·14	194·70	2·40
9	"	12		632·61	"	185·70	2·29
10	"	13⅓		512·41	"	176·58	2·18
11	"	14⅔		423·48	"	167·49	2·06
12	"	16		355·84	"	158·55	1·95
13	"	17⅓		303·20	"	149·86	1·85
14	"	18⅔		261·43	"	141·48	1·74
15	"	20		227·73	"	133·46	1·64
16	"	21⅓		200·16	"	125·84	1·55
17	"	22⅔		177·30	"	118·63	1·46
18	"	24		158·15	"	111·83	1·38
19	"	25⅓		141·94	"	105·45	1·30
20	"	26⅔		128·10	"	99·46	1·22
21	"	28		116·19	"	93·86	1·15
22	"	29⅓		105·87	"	88·62	1·09
23	"	30⅔		96·86	"	83·73	1·03
24	"	32		88·96	"	79·17	0·97
25	"	33⅓		81·98	"	74·92	0·92
26	"	34⅔		75·80	"	70·95	0·87
27	"	36		70·29	"	67·25	0·83
28	"	37⅓		65·35	"	63·79	0·78
29	"	38⅔		60·92	"	60·56	0·74
30	"	40	56·93		"		0·70

Solid Uniform Cylindrical Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula $w = 6{\cdot}71\frac{D^4}{L^2}$	Value of w	Value of c.	Calculated breaking weight in tons from formula, $r = \frac{wc}{w+4c}$.	Strength per sq. inch of section in tons.
8	9	10⅔		687·87	219·54	177·13	2·78
9	"	12		543·51	"	168·49	2·64
10	"	13⅓		440·24	"	159·78	2·51
11	"	14⅔		363·83	"	151·14	2·37
12	"	16		305·72	"	142·69	2·24
13	"	17⅓		260·49	"	134·51	2·11
14	"	18⅔		224·61	"	126·67	1·99
15	"	20		195·66	"	119·21	1·87
16	"	21⅓		171·96	"	112·15	1·76
17	"	22⅔		152·33	"	105·50	1·65
18	"	24		135·87	"	99·25	1·56
19	"	25⅓		121·95	"	93·41	1·46
20	"	26⅔		110·06	"	87·95	1·38
21	"	28		99·82	"	82·86	1·30
22	"	29⅓		90·95	"	78·11	1·22
23	"	30⅔		83·22	"	73·70	1·15
24	"	32		76·43	"	69·60	1·09
25	"	33⅓		70·43	"	65·77	1·03
26	"	34⅔		65·12	"	62·22	0·97
27	"	36		60·39	"	58·91	0·92
28	"	37⅓		56·15	"	55·82	0·87
29	"	38⅔	52·34				0·82
30	"	40	48·91				0·76

Solid Uniform Cylindrical Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formula $W = 4{\cdot}79\ \frac{n^4}{l^2}$	Value of W.	Value of c.	Calculated breaking weight in tons from formula $T = \frac{W c}{W + \frac{2}{3} c}$.	Strength per sq. inch of section in tons.
8	9	10⅔		491·04	187·03	145·47	2·28
9	"	12		387·99	"	137·37	2·15
10	"	13⅓		314·27	"	129·31	2·03
11	"	14⅔		259·72	"	121·44	1·90
12	"	16		218·24	"	113·85	1·78
13	"	17⅓		185·95	"	106·61	1·67
14	"	18⅔		160·34	"	99·76	1·56
15	"	20		139·67	"	93·31	1·46
16	"	21⅓		122·76	"	87·29	1·37
17	"	22⅔		108·74	"	81·67	1·28
18	"	24		96·99	"	76·45	1·20
19	"	25⅓		87·05	"	71·62	1·12
20	"	26⅔		78·56	"	67·14	1·05
21	"	28		71·26	"	63·00	0·99
22	"	29⅓		64·93	"	59·18	0·93
23	"	30⅔		59·40	"	55·64	0·87
24	"	32		54·56	"	52·37	0·82
25	"	33⅓		50·28	"	49·35	0·77
26	"	34⅔	46·48				0·73
27	"	36	43·11				0·67
28	"	37⅓	40·08				0·63
29	"	38⅔	37·36				0·58
30	"	40	34·91				0·54

Extract from the Scientific American.

O. B. M. in his article entitled "A Practical Inquiry into the Cause of the Fall of the Pemberton Mill," says:

"The cause of the fall of the Pemberton Mill has excited considerable speculation by some at a distance from the scene of the disaster, who are not well or correctly informed with all the details of facts in connexion with the construction of the Mill. I therefore propose to state some things which seem to be important facts concerning the cast iron pillars or columns and pintles, and their calculated strength, which are not generally known, and do not appear in the evidence before the coroner's jury."

"A distinguished engineer, before the coroner's jury, gave the breaking weight, according to Hodgkinson's rule, for a pillar 6 inches in diameter at bottom, 5¾ at top, ⅝ of an inch thick and 12 feet long, 221 tons; in which calculation he is correct for a pillar of those dimensions, with flat ends firmly fitted at top and bottom, as Hodgkinson describes. But that size and length of pillar does not come in, in this case; nor any others for which the gentleman gave the breaking weight. He gave the breaking weight for pillars of the given dimensions, which he calculated for another mill, as analogous

to those of the Pemberton Mill; but the dimensions of the pillars materially differ. It is a little singular that he was not requested to calculate the strength of the pillars under investigation; but it does not appear that any calculations for the breaking weight of the columns of the Pemberton Mill were before the jury. The largest pillars were in the first story or weave-room, and measured 6 inches in diameter at the base, 5 inches in diameter at the smallest part near the top, 5½ inches in diameter at the middle, 12½ feet long, and their mean thickness ⅝ of an inch. The formula by the above author for the breaking weight, is $44{\cdot}3 \times (5{\cdot}5^{3{\cdot}6} - 4{\cdot}25^{3{\cdot}6}) \div 12{\cdot}5^{1{\cdot}7} = 169$ tons breaking weight for the largest pillars, instead of 221; assuming that the ends were flat and firmly fitted at the top and bottom, which is not always done, and was not so in this case. Now according to Hodgkinson's experiments, pillars will sustain about three times as much weight when firmly fitted with flat ends, with disks or otherwise, than similar pillars with hemispherical ends capable of turning; or when the pressure is applied diagonally to pillars with flat ends. The bottoms of the pillars in this case were turned; but the pintles upon which the pillars rested were not turned or fitted at either end. The lower ends of the pintles (3 inches in diameter) rested on iron washers of the same diameter and ⅛ of an inch thick, and enough of these were put under the pintles to bring the timbers up to the proper height; the greatest number I noticed under one pintle was five."

"The pintles stood upon a base of washers 3 inches in diameter, which amounts to about the same as standing on rounded ends, for which we shall see a different rule is given. The pillars stood on the flanches of the pintles; the rough edges of the tops of the pillars were chipped off, and the plate 12 inches in diameter (not turned) rested on the pillars, and the timbers rested on the plate; many of the pillars were observed to touch at the top and bottom only on a part of their circumference when they were set up; and probably a very few, if any, had a complete bearing at both ends. In fact they stood upon a sort of 'centre.' It is clear, therefore, that the formula which the author gives for pillars with flat ends firmly fixed, does not apply in this case. But he gives another rule for pillars with rounded ends and capable of turning, or for those where the pressure is applied diagonally to pillars of flat ends, which it seems is the only safe rule to use in the case before us; he uses the co-efficint 13 instead of 44·3. It is as follows:—$13 \times (5{\cdot}5^{3{\cdot}6} - 4{\cdot}25^{3{\cdot}6}) \div 12{\cdot}5^{1{\cdot}7} = 49{\cdot}6$ tons, the breaking weight of the largest pillar in the Pemberton Mill. From a number of experiments of long continued pressure, it appears that it is not safe to load pillars more than ¼ of their breaking weight. The experiments were made where every thing was still; but for the pillars of a mill, with their continued jarring and oscillating motion caused by the machinery, though it be ever so little, the above weight is rather large. But the pillars in the second story were less able to sustain the weight on them than those in the first story. I find them 5⅜ inches in diameter at the bottom, 4½ at the small end, 4 15-16ths inches at the middle, with a mean thickness of ⅝ of an inch, and 11½ feet long. We will apply the rule for pillars not firmly fitted at the top and bottom. And $13 \times (4{\cdot}9375^{3{\cdot}6} - 3{\cdot}6875^{3{\cdot}6}) \div 11\ 5^{1{\cdot}7} = 40$ tons, their breaking weight. The weight they should permanently bear should not exceed 10 tons; and the weight they sustained, or were liable to sustain (though this room was more heavily loaded than those above), we cannot safely estimate at less than 18 tons."

Tables showing the Breaking Weight or the Calculated Strength of Pillars of similar dimensions as those Pillars referred to in the case of the Pemberton Mill—by several of Mr. Hodgkinson's formulæ.

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Value of w in tons from formula $w = 44{\cdot}34 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$.	Value of c	Calculated breaking weight in tons from formula $T = \frac{w\,c}{w + \frac{3}{4}c}$.	Strength per square inch of section in tons.
12	5·75	4·5	25·04	187·62	493·08	165·96	16·49
12	5·875	4·625	24·51	199·41	505·11	174·19	16·89
12	6·	4·75	24·	211·66	517·13	182·57	17·30
				$w = 44{\cdot}3 \frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$			
12	5·75	4·5	25·04	206·38	493·08	176·61	17·55
12	5·875	4·625	24·51	219·61	505·11	185·36	17·98
12	6·	4·75	24·	233·36	517·13	194·26	18·40
				$w = 42{\cdot}347 \frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}65}}$			
12	5·75	4·5	25·04	193·63	493·08	169·45	16·84
12	5·875	4·625	24·51	205·56	505·11	177·67	17·23
12	6·	4·75	24·	217·93	517·13	186·04	17·62

Hollow Uniform Cylindrical Pillars of Cast Iron, with Both Ends being Rounded or Irregularly Fixed.

				Calculated breaking weight in tons from formula $w = 13 \frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$	
12	5·75	4·5	25·04	60·56	6·01
12	5·875	4·625	24·51	64·44	6·25
12	6·	4·75	24·	68·48	6·48
				$w = 13 \frac{D^{3{\cdot}76} - d^{3{\cdot}76}}{L^{1{\cdot}7}}$	
12	5·75	4·5	25·04	82·29	8·17
12	5·875	4·625	24·51	87·76	8·51
12	6·	4·75	24·	93·75	8·88

Mean Breaking Weight from the above results:

				Flat Ends and Firmly Fixed.		Round Ends or Irregularly Fixed.		Ratio of strength
				Pillar.	Per sq. inch.	Pillar.	Per sq. inch.	
12	5·75	4·5	25·04	170·67	16·96	71·42	7.09	2·38
12	5·875	4·625	24·51	179·07	17·37	76·10	7·38	2·35
12	6·	4·75	24·	187·62	17·77	81·11	7·68	2·31

Hollow Uniform Cylindrical Pillars of Cast Iron, with Both Ends being Rounded or Irregularly Fixed

				Calculated weight of metal contained in the pillar in lbs.	Calculated breaking weight in tons from formula $w = 14{\cdot}78 \frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$	Strength per sq. inch of section per ton.
12	5·75	4·5	25·04	377·77	68·85	6·84
12	5·875	4·625	24·51	386·98	73·27	7·10
12	6·	4·75	24·	396·19	77·85	7·37

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Value of w in tons from formula $w = 44{\cdot}34\,\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of e.	Calculated breaking weight in tons from formula $Y = \frac{We}{W + \frac{2}{3}e}$.	Strength per sq. inch of section in tons.
12·5	5·	3·75	30·	117·34	420·92	114·05	13·27
"	5·5	4·25	27·27	154·23	469·02	142 96	14·93
"	6·	4·75	25·	197·47	517·13	174·46	16·53
				$w = 44{\cdot}3\,\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$			
"	5·	3·75	30·	128·09	420·92	121·49	14·14
"	5·5	4·25	27·27	169·25	469 02	152·36	15·91
"	6·	4·75	25·	217·71	517·13	185·92	17·61
				$w = 42{\cdot}347\,\frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}63}}$			
"	5·	3·75	30·	122·40	420·92	117·60	13·69
"	5·5	4·25	27·27	160·03	469·02	146·65	15·32
"	6·	4·75	25·	203·90	517·13	178·19	16·88

Both Ends being Rounded or Irregularly Fixed.

				Calculated breaking weight in tons from formula $w = 13\,\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$	
12·5	5.	3·75	30·	37·58	4·37
"	5·5	4·25	27·27	49·66	5·18
"	6·	4·75	25·	63·89	6·05
				$w = 13\,\frac{D^{3{\cdot}76} - d^{3{\cdot}76}}{L^{1{\cdot}7}}$	
"	5·	3·75	30·	49·83	5 80
"	5·5	4·25	27·27	66·96	6·99
"	6·	4·75	25·	87·47	8·28

Mean Breaking Weight from the above results.

				Flat Ends and Firmly Fixed.		Round Ends or Irregularly Fixed.		Ratio of Strength
				Pillar.	Per sq. inch.	Pillar.	Per sq. inch.	
12·5	5·	3·75	30·	117·71	13·70	43·70	5·08	2·69
"	5·5	4·25	27·27	147·32	15·39	58·31	6 09	2·52
"	6·	4·75	25·	179·52	17 00	75·68	7·18	2·37

Both Ends being Rounded or Irregularly Fixed.

				Calculated weight of metal contained in the pillar in lbs.	Calculated breaking weight in tons from formula $w = 14{\cdot}78\,\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$	Strength per sq. inch of section in tons.
12·5	5·	3·75	30·	335·92	42·73	4·97
"	5·5	4·25	27·27	374·31	56·46	5·89
"	6·	4·75	25·	412·70	72·63	6·88

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Value of w in tons from formula $w = 44{\cdot}34\,\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of c.	Calculated breaking weight in tons from formula $T = \frac{w\,c}{w + \frac{2}{3}c}$	Strength per sq. inch of section in tons.
11·5	4·5	3·25	30·66	99·58	372·81	97·90	12·86
"	4·9375	3·6875	27·94	130·40	414·91	122·52	14·47
"	5·375	4·125	25·67	166·43	457·00	149·37	16·01
				$w = 44{\cdot}3\,\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$			
"	4·5	3·25	30·66	108·06	372·81	103·92	13·65
"	4·9375	3·6875	27·94	142·23	414·91	130·15	15·37
"	5·375	4·125	25·67	182·39	457·00	158·72	17·01
				$w = 42{\cdot}347\,\frac{D^{3{\cdot}5} - d^{3{\cdot}5}}{L^{1{\cdot}69}}$			
"	4·5	3·25	30·66	103·87	372·81	100·98	13·27
"	4·9375	3·6875	27·94	135·31	414·91	125·73	14·84
"	5·375	4·125	25·67	171·90	457·00	152·64	16·36

Both Ends being Rounded or Irregularly Fixed.

				Calculated breaking weight in tons from formula $w = 13\,\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$	
11·5	4·5	3·25	30·66	31·71	4·16
"	4·9375	3·6875	27·94	41·74	4·92
"	5·375	4·125	25·67	53·52	5·73
				$w = 13\,\frac{D^{3{\cdot}76} - d^{3{\cdot}76}}{L^{1{\cdot}7}}$	
"	4·5	3·25	30·66	41·26	5·42
"	4·9375	3·6875	27·94	55·21	6·52
"	5·375	4·125	25·67	71·87	7·70

Mean Breaking Weight from the above results.

				Flat Ends and Firmly Fixed.		Round Ends or Irregularly Fixed.		Ratio of Strength
				Pillar.	Per sq. inch.	Pillar.	Per sq. inch.	
11·5	4·5	3·25	30·66	100·93	14·57	36·48	4·79	2·76
"	4·9375	3·6875	27·94	126·13	14·89	48·47	5·72	2·60
"	5·375	4·125	25·67	153·57	16·46	62·69	6·72	2·44

Both Ends being Rounded or Irregularly Fixed.

				Calculated weight of metal contained in the Pillar in lbs.	Calculated breaking weight in tons from formula $w = 14{\cdot}78\,\frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$	Strength per sq. inch of section in tons.
11·5	4·5	3·25	30·66	273·73	36·05	4·73
"	4·9375	3·6875	27·94	304·63	47·45	5·60
"	5·375	4·125	25·67	335·54	60·85	6·52

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Number of diameters contained in the length or height.	Value of w in tons from formula $w = 44{\cdot}34\,\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of c.	Calculated breaking weight in tons from formula $Y = \frac{w\,c}{w + \frac{2}{3}c}$
12·5	5·5	4·5	27·27	131·07	384·84	120·18
"	"	4·75	"	104·37	295·85	94·64
"	"	5·	"	73·84	202·04	66·19
"	"	5·125	"	57·10	153·33	50·87
"	"	5·25	"	39·15	103·42	34·69

Both Ends being Rounded or Irregularly Fixed.

				Calculated breaking weight in tons from formula $w = 13\,\frac{D^{3{\cdot}76} - d^{3{\cdot}76}}{L^{1{\cdot}7}}$	Flat Ends from the above results.	Ratio of Strength.
12·5	5·5	4·5	27·27	57·15	120·18	2·10
"	"	4·75	"	45·71	94·64	2·07
"	"	5·	"	32·49	66·19	2·03
"	"	5·125	"	25·15	50·87	2·02
"	"	5·25	"	17·31	34·69	2·00

Both Ends being Flat and Firmly Fixed.

				Value of w in tons from formula $w = 44{\cdot}34\,\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of c.	Calculated breaking weight in tons from formula $Y = \frac{w\,c}{w + \frac{2}{3}c}$
11·5	4·9375	3·9375	27·94	111·61	341·55	103·65
"	"	4·1875	"	92·36	263·37	83·91
"	"	4·4375	"	63·76	180·39	57·78
"	"	4·5625	"	49·41	137·10	44·49
"	"	4·6875	"	34·04	92·60	30·45

Both Ends Rounded or Irregularly Fixed.

				Calculated breaking weight in tons from formula $w = 13\,\frac{D^{3{\cdot}76} - d^{3{\cdot}76}}{L^{1{\cdot}7}}$	Flat Ends from the above results.	Ratio of Strength.
11·5	4·9375	3·9375	27·94	47·47	103·65	2·18
"	"	4·1875	"	38·26	83·91	2·19
"	"	4·4375	"	27·39	57·78	2·10
"	"	4·5625	"	21·29	44·49	2·08
"	"	4·6875	"	14·70	30·45	2·07

Taking the mean diameter of a diminishing or tapering pillar to be the correct rule, then according to Mr. Hodgkinson's formulæ for the breaking weight of hollow uniform cylindrical pillars of cast iron with flat ends and firmly fixed, and with rounded ends or irregularly fixed, we have the breaking weight for each of the pillars referred to in the Pemberton Mill as follows:

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	Flat Ends and Firmly Fixed. Calculated breaking weight in tons from formulæ $W = 44{\cdot}34 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$ $Y = \frac{We}{W + \frac{1}{2}e}$	Strength per square inch in tons.	Rounded Ends or Irregularly Fixed. Calculated breaking weight in tons from formula $W = 13 \frac{D^{3{\cdot}76} - d^{3{\cdot}76}}{L^{1{\cdot}7}}$	Strength per square inch in tons.	Ratio of Strength.
12·	5·875	4·625	174·19	16·89	87·76	8·51	1·98
12·5	5·5	4·25	142·96	14·93	66·96	6·99	2·13
11·5	4·9375	3·6875	122·52	14·46	55·21	6·52	2·21
			For the approximate Breaking Weight.				
			$W = 44{\cdot}3 \frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$ $Y = \frac{We}{W + \frac{1}{2}e}$		$W = 13 \frac{D^{3{\cdot}6} - d^{3{\cdot}6}}{L^{1{\cdot}7}}$		
12·	5·875	4·625	185·36	17·98	64·44	6·25	2·87
12·5	5·5	4·25	152·36	15·91	49·66	5·18	3·06
11·5	4·9375	3·6875	130·15	15·37	41·74	4·92	3·11

The following communication and accompanying diagrams have been forwarded to me by CHARLES METTAM, Esq., Architect and Civil Engineer, 429 Broadway, New York:—

WM. BRYSON, Esq., Architect and Civil Engineer, Chicago, Ill.

FRIEND BRYSON:—At your request, I send you a diagram of my mode of construction of Pillars for large Buildings when weight is to be carried and vibration sustained—I have also laid down the construction of the "Pemberton Mill" from the diagram you sent me as Fig. 6.

I give you five figures of my construction. Fig. 1, the dowel or *pintle* C, is movable and separate from the *pillars* A and B as in the *mill* construction, so as to be easily at all times handled in setting. The end which is in connexion with the pillar A forms a socket joint, the shoulder of same resting in a line of bearing with the pillars A and B, the end in connexion with the pillar B, forms a socket joint in itself and receives the end of the pillar B in a secure manner. Figs. 2 and 3 have their dowels D as part of the pillars A A. Fig. 2 has a socket joint in connexion with the pillar B, the same as Fig. 1. Fig. 3 has only one shoulder at its connexion with the pillar B, and dowel D, yet it will be seen that it is held securely in its place, and in direct line of bearing.

The Figs. 4 and 5 are of somewhat the same construction with the exception of the chairs *d*, which are light and therefore easily handled. In Fig. 4 the chair forms the socket joints for the pillars A and B.

In Fig. 5 the chair *d* forms only one socket-joint, which is for the pillar B, and is secured by a bolt to the head of the fixed dowel D of the pillar A.

The letters F and *e* refer in all cases to wood girders and beams, and the letter *a* to the flooring of the same material.

You will see from the diagrams 1 to 5 that the line of bearing is carried up in a vertical line, that no pillar or dowel is out of the line of bearing, which I consider of vital importance, also that the cores in all run straight through the pillars, which is not the

case in the "Mill" pillars at o o. The caps of Figs. 1 to 5 form a shoulder or bearing for the girders F, while the dowels C and D D D pass through in the usual manner.

In the construction of the "Mill pillars" to my mind there are many fatal and dangerous points which I will point out to you, although I am quite confident your own practical eye has long before this detected. In the first place, let us look at the Fig. 6, and what must strike the mind of any practical person is the total disregard of the laws of gravity in its whole construction. I have dotted the line of bearing, which will be seen to pass inside the pillars A and B. As the dowel C has to sustain the weight of the load on the pillar B which rests on the cap plate *b*, at which point it stands clear of any direct line of support from the pillar A. In the next place the base plate *t* receives the pillar B, and here the load is 1½ inches outside the direct line. And lastly, the cap of the pillar A at o o to my mind is weaker than any other part of the pillar. It must be admitted by all that castings of this kind are not at all times perfect, and any imperfections at the part o o, which may or may not have been the case in the "Mill" construction. Yet from this formation it must be considered as the most likely parts to give out or fracture in case of any settlement or sudden fall of any heavy weight, which is most likely to have been the case when we take into consideration that *none* of the pillars were turned off, only chipped off by hand. In this way the whole load of one entire tier of pillars and the section of the building depending on them may have rested on one square inch or much less. Yet I cannot divest my mind in examining the section of Fig. 6 at o o how neglectful those in charge were either from inattention or from inability of the knowledge of the operation of gravity, as all mechanical perfections of scientific building is the result of a clear and perfect knowledge of the operations of gravity, and from the ability to direct their course in the weight or downward tendency of the materials and the active force of such a building as the Mill.

It may be hard to trace to any one person solely the cause of the fall of the building. Yet it is quite clear that pillars of such pattern were wholly unfit for such a *structure*, even admitting the castings to be perfect. 1st. Why were the Pillars not turned off so as to fit close together in every part? 2d. Why was the pillar B, 1½ inches outside of the line of bearing of the dowel C? 3d. Why was the dowel C put standing in the centre of the cap plate *b*, solely and wholly depending on this plate for support? And lastly, why was the core of the pillar A made so at o o?

It may be that the contractor for the iron work had this pattern by him, and used it without giving it a moment's thought, and lo! for want of that moment's thought, what sorrow and desolation it has caused to many a poor family, not to mention the horrid death of most of its victims.

You must have met such patterns as Fig. 6; I know from myself that there aremany and made solely in order to save iron.

Yours, most faithfully,

May, 1862. Signed. CHAS. METTAM.

(To be Continued.)

Tensile Strength of Iron.—At the end of the case of iron manufactures from the Round Oak Iron Works of Lord Dudley (332 Lond. Exhib.), is a piece of cold rolled plate, having a sectional area of one square inch, that was tested at the government dockyards, and was found to support the enormous strain of upwards of fifty tons before it broke. This inch bar of iron would have supported a greater weight than that of 700 persons.—*Intellectual Observer, June*, 1862.

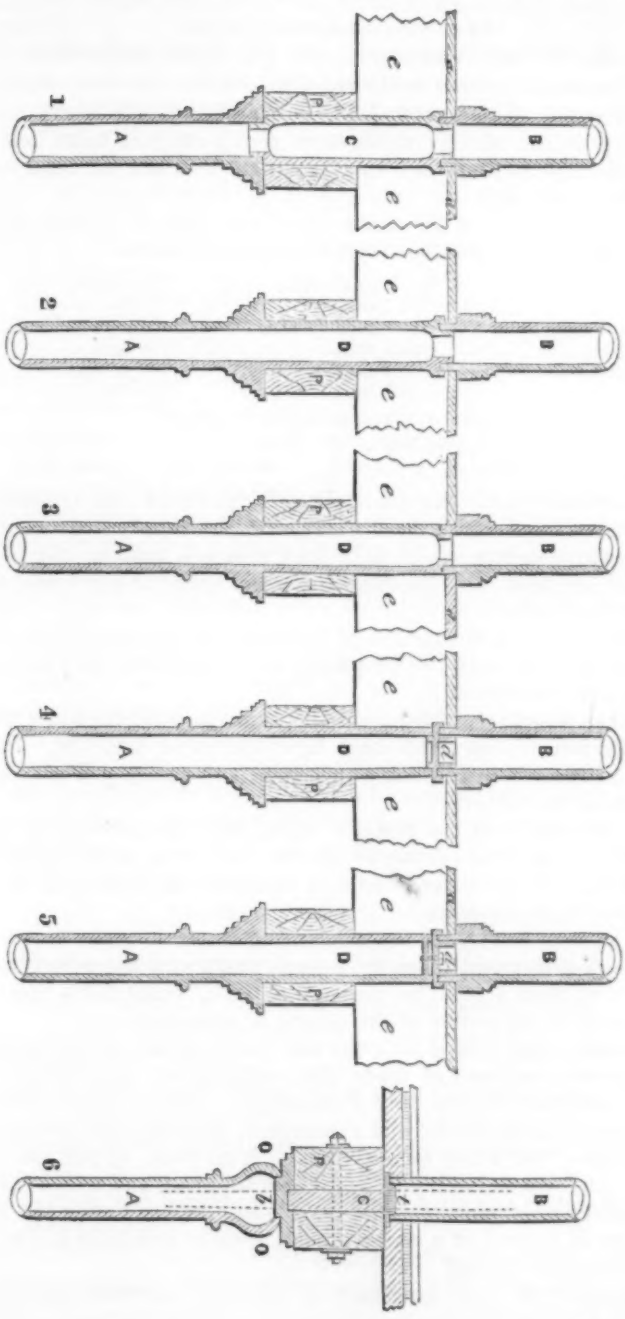


DIAGRAM OF METTAM'S MODE OF CONSTRUCTION OF PILLARS.

For the Journal of the Franklin Institute.

On Surface Condensers. By Mr. WILLIAM SEWELL.

Extracts from the Steam Log of the Steamer *John L. Stevens*, of the Pacific Mail Line.

The steamers *Sonora* and *John L. Stevens*, of the above named line, owing to the surface condensers giving out (the tubes being of but 16 oz. copper), they were run for a time with the jet condensers, using salt water only.

The following is from the steam log of the *John L. Stevens*, taking five trips with and five without the surface condensers:

	With Surface Condenser.	Without Surface Condenser.
Whole running time,	63 days 6 hours.	64 days 14½ hours.
Coal consumed,	2009 tons.	2191 tons.
Oil expended,	302 gallons.	630 gallons.
Tallow,	205 lbs.	625 lbs.

Difference in favor of Surface Condenser.

In time,	1 day 8½ hours.	In oil,	328 gallons.
coal,	182 tons.	tallow,	420 lbs.

The condenser used was too small, and furnished but one-half, or one boiler out of two with fresh water. If the supply had been full, twice the above saving would have been realized, making the saving in coal 18 per cent., and the increase in the speed of the vessel more than four per cent.

The following is a comparison of the practical operation, and of the powers required to work the air-pump, when connected with a surface and with a jet condenser:

To condense steam and form a vacuum in the condenser of a steam engine, the heat in the steam must be extracted or absorbed. This is done by bringing it in contact with a sufficient quantity of cold water or cold metallic surfaces.

In the jet condenser the steam is mixed with the condensing water, which absorbs the heat contained therein, and from which the boilers are supplied. If salt water is used to condense the steam, the boilers are supplied with the same.

In the surface condenser the condensing water is made to pass or flow through thin metal tubes by a small pump or other device, under a pressure of from 1 to 2 lbs. per square inch, which takes less than one per cent. of the power of the engine to operate it.

The steam is not mixed with the salt water as above, but is admitted to the outer surfaces of these thin metal tubes, which absorb the heat and condense it into pure fresh water. This water is taken by the feed-pump at each stroke of the engine, and returned to the boilers, and being the exact quantity taken from them in the steam, is the exact quantity necessary to keep them supplied, and which insures greater safety than when the supply of water depends upon the labor and danger of neglect of a water tender, serious accidents having occurred from such neglect.

The quantity of water necessary to condense a certain quantity of steam varies as the temperature thereof, the colder the water the less

quantity is necessary, being from 15 to 45 times that contained in the steam.

Ordinary water contains a certain quantity (said to be 5 per cent.) of atmospheric air. With the jet condenser this is admitted with the water to condense the steam, but being permanently elastic is not condensed, but expands into a large volume in the vacuum space, and impairs the vacuum. All this has to be discharged by the air-pump against the pressure of the atmosphere of some 14 to 15 lbs. per square inch.

In warm climates large quantities of water are necessary, owing to its high temperature, and a proportional large quantity of air enters with it, and requires a large air-pump to discharge it. To relieve the engine of this enormous load, it is found to be of advantage to use less injection water to condense the steam, and consequently get less vacuum; the loss of power from this cause being less than when the air-pump is overloaded.

This air and water is not admitted into the vacuum space of a surface condenser; only the water contained in the steam (being only from $\frac{1}{15}$th to $\frac{1}{45}$th part that required above) is to be discharged by the air-pump; consequently a very much smaller one is sufficient to obtain as good and generally a better vacuum. There is a larger cooling surface exposed to the steam, the condensation is more instantaneous, and the maximum vacuum is sooner formed at the end of each stroke of the engine.

The power to work the air-pump independent of the friction, varies as the quantity of water discharged by it. In middle latitudes, with a moderate temperature of the water used to condense the steam, the power required to operate the air-pump is allowed to be 10 per cent. of the power of the engine when attached to a jet condenser.

From the foregoing it will be seen how much less power is necessary to operate the air-pump when connected with a surface than with a jet condenser. If but one-half is saved, it is 5 per cent. of the entire power of the engine.

Estimate of the value of the gain referred to.

1st. As before stated, less power necessary to work the air-pump,	·05
2d. The heat lost in the hot water blown out to keep the boilers even partially clean,	·12
3d. The heat lost by incrustation on the fire surfaces, in some cases more than 20 per cent.,	·05
	·22 per ct.
4th. A higher pressure of steam may be used and a greater benefit obtained by expansion.	

Where the losses named above are prevented or saved, less coal and boilers (and less water in them) will exert the same power, requiring fewer firemen and coal trimmers, thereby saving in the daily expenses of the vessel for coal, wages, and food.

If a certain vessel with a jet condenser requires 1000 tons of coal per trip or voyage, with a surface condenser 800 tons will exert equal power.

And if the displacement of the vessel is 25 tons per inch of immersion, she will draw 8 inches less of water, not counting the saving in weight of boilers and water, and drawing less water will make greater speed (as shown by the *John L. Stevens*), and accomplish the distance in less time.

Boilers using salt water burn less fuel when new and clean, than when some time in use and covered with incrustation: they also require great labor to clean them. With fresh water they are always as clean as when new.

From the foregoing, what is lost by using salt water in the boilers is apparent.

The result, as shown in the steam log of the steamer *John L. Stevens*, is taken from the actual practical operation at sea, during a period of 64 to 65 days steaming, with each kind of condenser. The boilers were only half supplied with fresh water, and only one-half the benefit was realized that would have been if fully supplied. Moreover, the engines labored under the disadvantage of having to operate two air-pumps, one of which had to discharge all the water used to condense the steam against the pressure of the atmosphere, taking at least 5 per cent. of the power of the engine more than with a close plan of surface condenser. Yet with all these disadvantages there was a saving of nine per cent. of fuel, and a gain of more than two per cent. in the speed of the vessel.

There are boilers using fresh water that have been in constant operation from 15 to 20 years, requiring but little repairs during that time.

Extra Cost of the Condenser.—Vessels fitted with two engines have two air-pumps. When a surface condenser is attached, one is sufficient as an air-pump, the other to make the water flow through the tubes. This pump, as before stated, works against a pressure of but 1 to 2 lbs. per square inch, instead of against a pressure of 13 or 14 lbs. per square inch when used with a jet condenser. The other pump, although used as an air-pump, has less than one-fourth part of the labor it would have if used with a jet condenser, having only to discharge the water contained in the steam.

By this arrangement there is no extra cost for pumps, but only for the tubes and tube sheets for the condenser proper; and as less boiler will exert the same power, the saving in cost will partly pay for the extra cost of the condenser.

In ordinary business transactions 20 per cent. is considered a fair profit, but the owner of a steamship using salt water in the boilers pays for and carries in his vessel one-fifth or 20 per cent. more boilers (and the additional water contained therein) than is necessary.

He also pays for each day the vessel is steaming for 20 per cent. more coal than is necessary to exert the same power.

This extra coal is not only *wasted*, but it requires additional firemen and coal trimmers to take it on board and get rid of it, besides taking up the freight room, and making the vessel draw more water, thus lessening her speed.

For the Journal of the Franklin Institute.

Momentum and Vis Viva. By D. Wood, Prof. Civ. Eng. University of Michigan.

When we consider that eminent scholars have taken different views upon the measure of the force in a moving body, it is not strange that students, while yet in the elements of mechanical science, should be at a loss to know whether the force varies as the velocity or as the square of the velocity. They do not see why the momentum does not express the force as well as the *vis viva;* or they fail to distinguish between the nature of these two forces; or they do not get a very clear conception of either.

It is not my purpose in this article to enter into a discussion of the measure of force, but to try to show clearly to students, the nature of the above named forces by showing the office which each performs in the same moving body.

Vis Viva, sometimes called "living force," is a mere conventional term to express the product of the mass of a body multiplied by the square of its velocity. It bears a direct relation to the *work* which the moving body is capable of doing; being just double the work. For whatever be the work which it does or is capable of doing, we know that the same amount of work may be expended in raising a weight through a sufficient height.

Let W = the weight.
h = the necessary height.
M = the mass of W.
V = the velocity required in falling through h.

Then it is well known that W h = the work done. But from the law of falling bodies, $V = \sqrt{2gh}$, or $h = \frac{V^2}{2g}$.

$$\therefore W h = \frac{W V^2}{2g} = \tfrac{1}{2} M V^2.$$

But $M V^2$ = the living force; hence the work which a moving body is capable of doing is one-half the living force, or *vis viva*, of the body.

To work is to overcome resistance; hence a body may move and do no work. The fact that it has mass and moves, is evidence that it is capable of doing work; and if it changes its velocity it either *performs work* or has work expended upon it.

The *force* which is stored in a moving body, is a *force of inertia;* hence *it is equivalent to the force which would cause the body to move from a state of rest to a velocity* V, *when free to move without any resistance.* We see then that when a body is moved against any resistance; as air, water, or friction; that the force which would give the body a velocity V, may be divided into two parts; 1st, that which directly overcomes the resistance of the air, water, and the like; and, 2d, that which overcomes the inertia of the body; and it is by know-

ing the terminal velocity and the mass that we are able to tell the amount of resistance (in lbs. feet) that the body would overcome without applying to it any additional force.

Before developing this idea further, let us turn our attention to the subject of momentum. *Momentum* is also a *conventional name* for the expression M V. If we were permitted to call it a force, we would say that it is also a force of inertia. It is also called "quantity of motion;" for by knowing the masses of two bodies, elastic or non-elastic, and the velocity of one before impact, we can find their velocities after impact; bodies being supposed to be free to move.

Now in order to show the office which each performs in moving bodies, let us take a few examples.

Suppose two perfectly non-elastic bodies of equal mass (and consequently of equal weight) move with equal velocities in opposite directions; what will be their condition after impact?

Now because their *momenta* are equal, we know that they will destroy each other's motion, and hence so far as their *motion* is concerned they will be in a state of rest. And this is all that we can determine from the principle of momentum. It relates to the *motion* of the masses. But as a fact we know that before they came to rest there was a compression of the two bodies, and hence work was done. The amount of this compression depends upon the *vis viva* of the two bodies. By momentum we decide that the bodies will come to rest, whatever be their velocities, provided that they are equal; by *vis viva* we decide that the amount of compression is directly proportional to the square of the velocities. *Vis viva* pertains to compression, or more generally, to the displacement of particles in respect to each other; hence it is sometimes called the penetrating power.

Suppose that the bodies are perfectly elastic; then without any knowledge of the principle of *vis viva*, we decide that the bodies will have equal velocities after impact, but in opposite directions. By *vis viva* we know as before, that the amount of compression is proportional to the square of the velocities; but on account of the elasticity the *vis viva* (or work) is all restored, so that there is no loss of *vis viva* in perfectly elastic bodies.

Suppose the bodies unequal, non-elastic, and move in opposite directions.

Suppose A weighs 200 lbs. and has a velocity of 2 feet,
and B " 20 " " " " 20 "
required their condition after impact.

With regard to the *motion of their masses*, they will come to rest; for their momenta are equal; being $200 \times 2 = 20 \times 20 = 400$ lbs. feet.

But the *vis viva* of A is proportional to $200 \times 2^2 = 800$,
" " B " $20 \times 20^2 = 8000$;

hence B performs 10 times the labor of A in producing the compression of the two bodies. This at first may appear paradoxical; but two considerations will enable us to make it clear.

1st, It is possible for one body to do all the labor of compressing both bodies; thus, suppose one body moves against another at rest. Now the body at rest has no *vis viva* (or work) stored in it, but the moving body has; hence it performs all the work of compression.

2d, In the example under consideration; if A can perform 10 times the labor of B; then A would penetrate a clay-bank 10 times as far as B; if the bodies were of equal size: now how can this be if they destroy each other's motion by impact?

I think the difficulty disappears at once by observing that A has 10 times as many particles to bring to rest as B; and hence B must perform 10 times the labor of A to bring them to rest.

It is worthy of notice that if the momentum of two bodies are equal, then their *vis vivas* are inversely proportional to their masses. For we have $M V = M' V'$;

$$\therefore V^2 = \frac{M' V'}{M}.$$

Substituting this value V in the expression for the *vis viva*, gives

$$\frac{M V^2}{M' V'^2} = \frac{M \left(\frac{M' V'}{M}\right)^2}{M' V'^2} = \frac{M'}{M}$$

It is well known that if the impact of two non-elastic bodies takes place while they are moving in the same direction, their momentum after impact is the same as before, but there is a loss of *vis viva*. Now this loss is expended in compressing, or otherwise disfiguring the bodies.

Other illustrations might be given, but I trust that these will throw some light upon the dark points which may have arisen in the mind of some reader.

In the last example I said that the *vis viva* of A is proportional to 200×2^2; but the true value is $\frac{200}{g} \times 2^2 = \frac{200}{32\frac{1}{6}} 2^2$; and similarly for B. Many writers use the weight for the mass too frequently, thereby producing slight confusion. By making such free use of it, the student is at a loss to know when it is necessary to use the mass.

On the Difference in the Properties of Hot-Rolled and Cold-Rolled Malleable Iron, as regards the power of receiving and retaining Induced Magnetism of Subpermanent Character. By GEORGE BIDDELL AIRY, Esq., F. R. S., Astronomer Royal.

The author states that he had been desirous of examining whether differences in the degree of change of subpermanent magnetism, such as are exhibited by different iron ships, might not depend on the temperature at which the iron is rolled in the last process of its manufacture. By the good offices of Mr. Fairbairn he had received gratui-

tously from Richard Smith, Esq., Superintendent of Lord Dudley's Iron Works at the Round Oak Works near Dudley, twenty-four plates of iron, each 16 ins. long, 4 ins. broad, and $\frac{1}{4}$ inch thick; twelve of which, after having been manufactured with the others in the usual way, had been passed through rollers when quite cold. Each set of twelve was divided into two parcels of six each, one parcel being cut with the length of the bars in the length of extension of the fibres of the iron, the other being cut with the length of the bars transverse to the length of extension.

For experimenting on these, a large wooden frame was prepared, capable of receiving the 24 bars at once, either on a plane transverse to the direction of dip at Greenwich, or on a plane including the direction of dip. In some experiments, these planes were covered with flag-stones, and the bars were laid upon the flag-stones; in others, the bars were laid immediately upon the wood. While there lying, they were struck with iron or wooden hammers of different sizes. The bars of the different classes were systematically intermingled, in such a way that no tendency of the arms to give blows of a different force or kind in special parts of the series could produce a class-error in the result. For examination of the amount of polar magnetism in each bar, it was placed at a definite distance (5 inches) below a prismatic compass, which was used to observe the apparent azimuth of a fixed mark; the bar was then reversed in length, and the observation was repeated in that state.

The number of experiments was 21. They were varied by difference in the succession of positions of the bars, difference of time allowed for rest, difference in the violence of the blows, &c.

The principal results appear to be the following:—

1. The greatest amount of magnetism which a bar can receive, appears to be such as will produce (on the average of bars) a compass-deviation of about 11°, the bar being 5 inches below the compass. It was indifferent whether the bars rested on the stone or on wood, or whether they were struck with iron or with wood, the bars lying on the dip plane while struck.

2. When the bars, thus charged, lay on the plane transverse to the dip, they lost about one-fifth of their magnetism in one or two days, and lost very little afterwards.

3. When the charge of magnetism is smaller than the maximum, the diminution in a day or two is nearly in the same proportion as for the maximum.

4. The effect of violence on the bars, when lying on the plane transverse to the dip, is not in all cases to destroy the magnetism completely, sometimes it increases the magnetism.

5. The Cold-Rolled Iron receives (under similar violence) or parts with (under similar violence) a greater amount of magnetism than the Hot-Rolled Iron, in the proportion of 6 to 5.

6. There is some reason to think that the Hot-Rolled Iron has a greater tendency to retain its primitive magnetism than the Cold-Rolled Iron has.

7. There is some reason to think that, when lying tranquil, the Hot-Rolled Iron loses a larger portion of its magnetism than the Cold-Rolled Iron loses in the same time.

Proc. Royal Society, May 15, 1862.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, Oct. 16, 1862.

J. C. Cresson, President, in the chair.

John Agnew, Vice President, }
Isaac B. Garrigues, Recording Secretary, } Present.

The minutes of the last meeting were read and approved.

Letters were read from the Royal Geographical Society, London.

Donations to the Library were received from the Royal Society, the Royal Geographical Society, and the Statistical Society, London; the Canadian Institute, Toronto, and the Natural History Society, Montreal, Canada; William Bryson, Esq., Chicago, Illinois; the Regents of the University of the State of New York, Albany, N. York; the Commissioner of the U. S. Patent Office, and Frederick Emmerick, Esq., Washington, D. C.; Edward F. Moody, Esq., and Thomas C. Clark, Esq., Camden, and William H. B. Thomas, Esq., Mount Holly, N. J.; Jacob Maas, Esq., Prof. John C. Cresson, Prof. John F. Frazer, George M. Conarroe, Esq., and the Société Frangaise de Bienfaisance, Philadelphia.

A donation to the Cabinet of Minerals, &c., was received from Capt. Jabez Jenkins, Elizabeth City, New Jersey.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's statement of the receipts and payments for the month of September was read.

The Board of Managers and Standing Committees reported their minutes.

Twenty-five resignations of membership in the Institute were read and accepted.

Candidates for membership in the Institute (6) were proposed, and the candidates (2) proposed at the last meeting were duly elected.

Mr. H. Howson exhibited specimens of the *Hibiscus Moscheutos* in various stages of manufacture, and made the following remarks:

I had the honor of submitting to the Members of this Institute some months ago, several specimens of a fibre similar to, but of a much more crude character, than those now before the meeting.

The fibre constitutes the outer covering or bark of the stalks of a North American perennial plant, of the order *Malvaceæ*, known as the *Hibiscus Moscheutos*, or *Palustris*—the plant as well as the fibre having received the name of American Jute; although the term may

be considered inappropriate, for the reason that the Jute of the East Indies is the production of the *Cochorus Olitorius*, or *Cochorus Capsularis*, neither of which plants has any relation to the order *Malvaceæ*, and for the further reason that the fibres of the *Hibiscus* are not so liable to become deteriorated by exposure and washing in alkaline leys as those of the Jute.

The utility of the fibres of this plant was brought to light by Mr. W. J. Cantelo, who, during the last three years, has been actively engaged in examining and testing the peculiarities of plants indigenous to the Northern States, with the view of discovering a fibre available as a substitute for linen rags in the manufacture of paper, for hemp in the making of ropes, matting, &c., and as a partial substitute for cotton in the manufacture of textile fabrics.

A patent was granted on May 13th, last, for the utilizing of the fibres of the *Hibiscus Moscheutos*, and this patent is now owned jointly by Mr. Cantelo, the discoverer, and his assignees, Messrs. Stuart & Peterson, the enterprising stove and hollow ware manufacturers of this city.

These gentlemen, aided by Mr. Cantelo, have during the last eighteen months been actively engaged investigating the subject, and prosecuting experiments with the view of determining the properties of the plant, the strength and value of the fibre, the requirements demanded for its proper cultivation, and the amount of fibre which can be obtained from one acre of ground.

The proprietors of the patent are now prepared to lay before the public the satisfactory and highly important results of their very careful experiments.

The *Hibiscus Moscheutos*, is indigenous to the Northern States, and grows in abundance in swampy lands of Pennsylvania, New Jersey, New York, &c.; in the marshes of Burlington County, New Jersey, it is especially abundant.

In its natural state, stalks of the plant, when at their full growth, are from five to six, and even seven feet high, and vary from a quarter of an inch to five-eighths of an inch in diameter. The number of stalks from one root vary from eight to sixty, and eighteen stalks of an average size will produce four ounces of disintegrated fibre.

An acre of marsh land, in the neighborhood of Burlington, N. J. was ploughed, and seeds of the "*Hibiscus Moscheutos*," spread along the furrows on the 28th of April last. On examining the land in September the ground was found to be thickly studded with seedlings, of which the drawing produced at the meeting represents a specimen. It should be understood that little or no care was taken to weed the ground, and to give that attention to the young plants which will be advisable during their first growth.

It had been discovered by previous experiment that on cutting one of the stalks one season, a dozen or more would take its place the next, and that the plants would require no attention after the first year's growth. As to any liability of the plants becoming deteriorated from the ravages of insects, it was found that in no instance could

any marks of insect depredations be observed on the stems, leaves, or roots of the plant.

The next point to be ascertained was the amount of fibre which could be produced from an acre of ground, planted with the *Hibiscus Moscheutos.*

This has been determined by a close observation of the plant in its natural state, and by weighing the fibre taken from a number of stalks of average dimensions. At a moderate calculation, and taking into account the probability of loss from unforeseen causes, three and a half tons of disintegrated fibre can be derived from one acre of ground.

Another important point decided was the facility with which the fibre or bark of the stalks could be separated from the pith.

It was discovered that this could be done with ease and rapidity, even without the aid of machinery, which can be readily applied to the purpose.

The bark after being detached from the pith is at once removed to a very simple apparatus, invented by Mr. Cantelo, when the bark is reduced in a comparatively short time to the disintegrated fibrous condition shown by the specimens exhibited, the fibre in this state being ready for the market, either for conversion into rope, or for paper stock.

As to the value of the fibre it has been declared by experienced rope manufacturers to be far superior to Manilla hemp or Jute, the specimens of rope exhibited being fully equal in strength and pliability to ordinary hempen rope.

Two prominent paper manufacturers of this city have estimated the fibre to be worth $100 per ton, to be used as a substitute for linen rags in the manufacture of paper.

The utility of the fibre as a substitute, or partial substitute, for cotton, woolen, or flax, in the manufacture of textile fabrics, has not yet been fully tested, but I am satisfied that the members present will, after an examination of the specimens before them, be convinced that the utility of the fibre is not limited to the making of rope and paper, but that it is admirably adapted to the manufacture of many textile fabrics.

When we take into account the fact that fibre of the value of at least three hundred dollars can be derived from one acre of ground; that the ground necessary for its growth is of such a swampy character as to be unfit either for the cultivation of ordinary farm produce, or for grazing purposes; that the plants require no attention after the first year's growth, but, unaided by any chemical or mechanical appliances, present a yearly supply of stalks ready to be converted into fibre; when we consider the hardihood of the plant and its freedom from the ravages of insects, we must admit that the greatest credit is due to Mr. Cantelo, that his discovery is of the greatest importance, as it opens new avenues for the exercise of agricultural, mercantile and mechanical pursuits, and tends to the utilizing of the swampy deserts, with which our Northern States abound.

I am anxious, Mr. President, that the members present should understand that the specimens of fibre have been prepared without the

aid of any complex machinery or elaborate chemical apparatus—the appliances which the inventor has called to his aid being of the most simple character.

The samples of rope were made by hand; the maker asserting that had they been made by the usual machinery the rope would have been of a much superior character.

Although the specimens are most satisfactory, and are sufficient to convince the most skeptical observer of the importance of the discovery, its value will necessarily be still further developed by the aid of appliances which may be demanded by the preparation of the fibre on a large scale.

The attention of Mr. Cantelo has not been confined to the fibres of the *Hibiscus Moscheutos* alone. Few plants in this and the neighboring state of New Jersey have escaped his searching investigation and his elaborate tests.

He has discovered that the plant next in importance to the *Hibiscus* as regards its fibre-bearing qualities is the *Abutilon Aricennæ*, an annual, readily cultivated, and hitherto considered a useless weed. The fibres of this plant, a specimen of which I submit for inspection, are of a silky character and extraordinary strength.

The utilizing of the fibres of the *Abutilon*, as well as the disintegrating process alluded to, form subjects for further applications for patents.

In conclusion, I would remark that a company is about being organized for the cultivation, or I should rather say planting, (as cultivation, in the ordinary sense, is unnecessary,) of the *Hibiscus Moscheutos*, and the preparation of the fibres for the market, the proprietors of the patent to be the principal stockholders. The members present will be satisfied that success must attend the efforts of an enterprising company who follow up with energy the prosecution of this important invention or discovery, which has been developed with such praiseworthy zeal by Mr. Cantelo and his assignees.

Mr. Howson also exhibited a Camera Obscura invented by Mr. G. T. Kolb, of this city. The camera consists of an ornamental box, on one side of which are the tubes holding the lenses. In the opposite side is an oblong opening surrounded by an eye tube placed at such an angle that the operator can see the bottom of the box, on which is placed a sheet of paper. By a suitable arrangement of mirrors the image is reflected on the paper in an upright position instead of reversed, as is usually the case in portable cameras. The reflected image can be easily traced with a pencil upon the paper by introducing the hand through an opening at the side of the box, a loose apron hanging over the opening and the arm to exclude the light.

G. L. Witsil's machine, for agitating and mixing substances, was also exhibted by Mr. H. The apparatus consists of a vessel in which revolve, in opposite directions, two spiral rods, one spiral being right-handed and the other left-handed. The currents produced by the revolutions of the spirals cause a thorough agitation and admixture of

the contents of the vessel. This mixer is exceedingly useful for mixing dough, clay, and other plastic substances, also for beating eggs. It may also be used as a churn.

Mr. Jones exhibited a diagram of an improved Oil Cup invented by Chief Engineer Wood, U. S. N. In an oil cup of the usual form is secured a tube which surrounds the opening in the bottom of the cup. The oil is deposited on the bearing from the cup by a syphon, the longer leg of which is placed in the tube, the shorter end extending beneath the surface of the oil. When the machinery is not in operation the syphon is lifted out of the tube and placed in the cup, where it is always at hand ready for use when required.

Mr. Howson exhibited G. G. Custer's improved Coal Oil Lamp; in which a reservoir containing a supply of water is situated immediately below the perforated air chamber of the lamp, so that the steam caused by the heating of the water will mix with the air and impinge against the base of the flame, rendering the latter clear and brilliant, and preventing the disagreeable odor which is usually emitted by these lamps while burning.

Coal Oil Lamp, invented by Mr. Mowry, was also exhibited. The peculiarity of this lamp consists of two curved and perforated projections, so situated in respect to the burner that they tend to spread the flame and cause it to burn with brilliancy, and unaccompanied with smoke, in the absence of the usual chimney.

Mr. Howson remarked that great attention had been recently paid by the ingenious to the construction of coal oil lamps, and that great credit was due to Mr. Merrill, of the firm of Warner, Miskey & Merrill, of this city, for the many ingenious, simple and effective improvements made by him, many of which had been exhibited at meetings of this Institute, a number being upon the table.

A Spring Governor, for steam engines, patented by Messrs. Evans & Jenkins, of this city, was exhibited. This governor is so constructed that the force applied to overcome the rigidity of the spring is transmitted through a leverage, constantly increasing as the rigidity of the spring increases, thereby so equalizing the action of the spring that the operation of the governor will be uniform under all circumstances.

Mr. A. B. Davis exhibited a weighing scale for iron manufacturers. By the arrangement of a series of levers, which can be alternately connected to and detached from the platform at the scale, the proper quantity of each article required in the manufacture of iron may be measured without altering the position of the weights upon the beams; one beam being reserved for each ingredient.

Another advantage obtained is that the weights may be secured to the beams in the proper position, and the case containing them locked up, the proportions of the ingredients used being thus kept secret from the workmen, while small pins secured to the beams and projecting through slots in the case, show when the beams are raised.